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Space Network
TDRSS KSAR Upgrade Project
Requirements Specification

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National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, Maryland

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TDRSS KSAR Upgrade Project
Requirements Specification

ORIGINAL
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PREFACE

The purpose of this document is to define the functional and performance requirements for the Space Network (SN) Tracking and Data Relay Satellite System (TDRSS) K-band Single Access Return (KSAR) Upgrade Project (TKUP). The document also defines the operations and transition concepts for the TKUP.

This document is under the configuration management of the Code 452 SN Configuration Control Board (CCB).

Configuration Change Requests (CCRs) to this document shall be submitted to the SN CCB, along with supportive material justifying the proposed change. Changes to this document shall be made by document change notice (DCN) or by complete revision.

Questions and proposed changes concerning this document shall be addressed to:

TKUP Project Manager
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TO BE RESOLVED / TO BE DETERMINED LIST

Section / Table	Page Number	To Be Resolved (TBR) / To Be Determined (TBD) List Item
Table 4-5 Item c5	4-8	LDPC coded (8160,7136) (TBD)
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4.3.2. b. 13	4-10	SQPSK, Single Channel Configuration with LDPC and/or TPC (TBD).
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4.3.7.2 Heading	4-16	Low Density Parity Check Decoding (TBD)
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4.3.7.3. c	4-17	Perform decoding as specified in Section 4.3.9 and (TBD-TPC reference document).
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4.4.3a	4-28	"at a level that is 6 dB (TBR) less than the C/N_o required for a BER of 10^{-5}"

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Document History			
Document Number	**Status/Issue**	**Publication Date**	**CCR Number**
452-RS-TKUP	Original	August 2005	452/242

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DCN CONTROL SHEET

DCN Number	Date/Time Group (Electronic DCN Only)	Month/Year	Section(s) Affected	Initials

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SECTION 1. INTRODUCTION

1.1 Background

The Space Network (SN) consists of a constellation of nine Tracking and Data Relay Satellites (TDRS); two ground terminals, the Second Tracking and Data Relay Satellite System (TDRSS) Ground Terminal (STGT) and the White Sands Ground Terminal (WSGT) at the White Sands Complex (WSC) in New Mexico; and another ground terminal, the Guam Remote Ground Terminal (GRGT) at the Guam Remote Station (GRS) in Mariana Islands. The ground terminals were designed and implemented in the early 1990s, and some of the systems, including the K-Band Single Access Return (KSAR) high rate equipment and the Data Interface Subsystem (DIS) high rate switches, are reaching obsolescence. The existing ground terminal equipment is expected to remain operational for at least another ten years.

National Aeronautics and Space Administration (NASA) Mission Offices (Exploration Systems, Space Operations, Science and Aeronautics Research) and other potential SN Customers are expected to evolve to higher data rate communications exceeding the 300 Mbps maximum currently available via the SN 225-MHz return channels.

In response to these expected needs, the SN will upgrade the SN KSAR service under the TDRSS KSAR Upgrade Project (TKUP). The goals of the TKUP are to:

- Address the KSAR high rate equipment and DIS high rate switch equipment obsolescence.
- Provide enhanced KSAR services by adding the capabilities to process bandwidth efficient signal designs (increasing the maximum data rate from 300 Mbps to 625 Mbps).
- Provide Single Access Antenna (SAA) autotrack capability for the new signal designs.

These new signal designs will also enable SN Customers to realize significant reductions in required Effective Isotropic Radiated Power (EIRP) compared to existing uncoded KSAR services operating between 150 Mbps and 300 Mbps.

1.2 Purpose

The purpose of this document is to specify the functional, performance, and interface requirements for the TKUP.

1.3 Scope

The system requirements in this document will only address TKUP changes and will avoid documenting requirements for existing systems unmodified by TKUP. The requirements in this document will impact high rate Hardware Configuration Items (HWCIs) in the following subsystems located at the WSC and GRS:

a. User Services Subsystem (USS) high rate portion of KSAR equipment.
b. DIS in STGT and WSGT.
c. GRGT Local Interface (LI) switch high rate portion only.

The requirements in this document will also impact the requirements for the following Computer Software Configuration Items (CSCIs):

a. Network Control Center Data System (NCCDS).
b. DIS.
c. Executive (EXC).
d. USS.
e. Workstation (WKS).

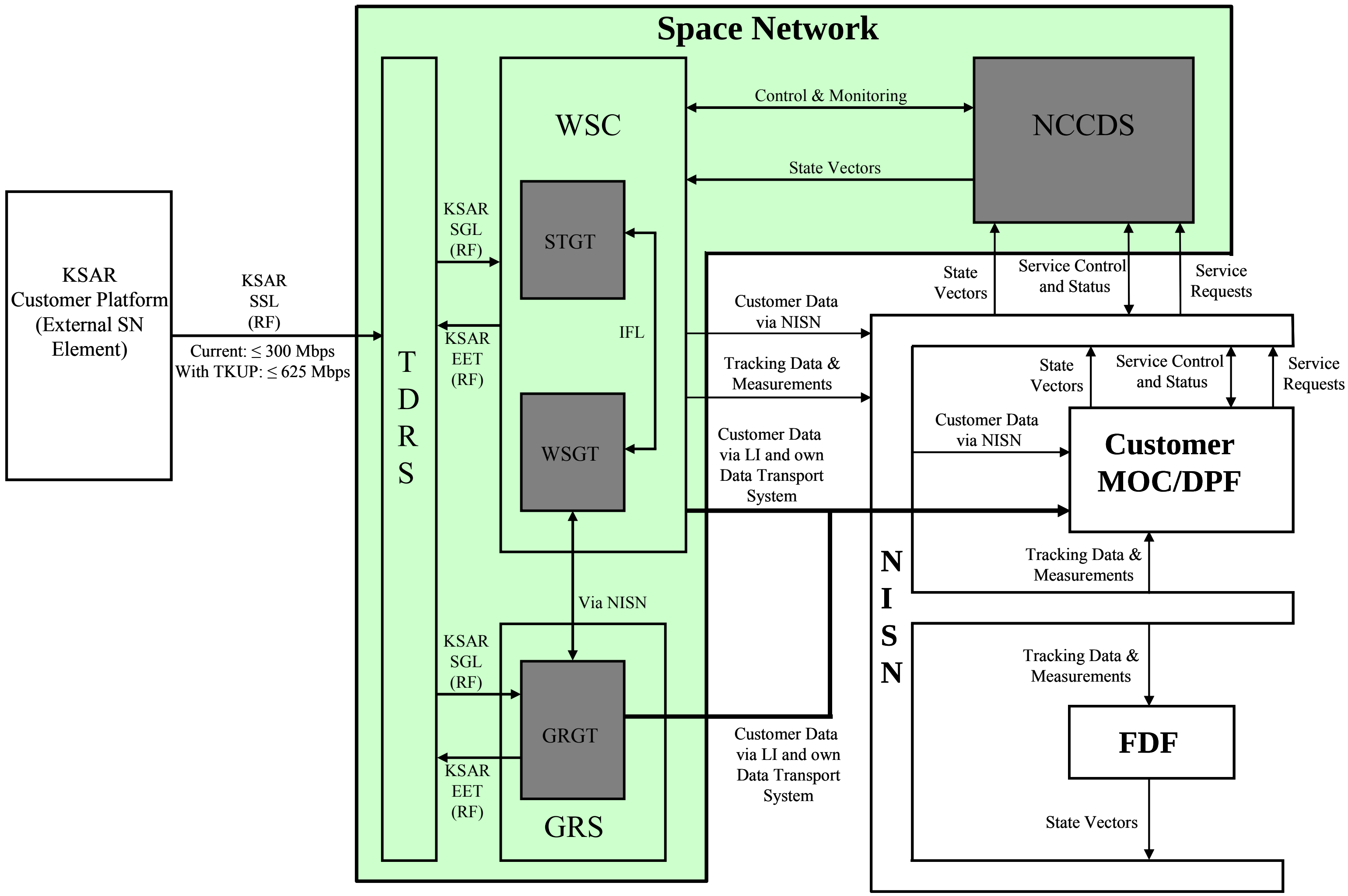
Throughout the document, the term "Turbo Product Code (TPC) and/or Low Density Parity Check (LDPC)" is stated when defining the coding requirements for the new TKUP customer signal formats. A final decision on whether to use TPC, LDPC, or both codes will be made based on the results of the TKUP demonstration that is planned for CY06. The selected coding method will be presented at the TKUP Critical Design Review (CDR). Also, after the TKUP demonstration, a DCN for this TKUP Requirements Specification (RS) will be developed to finalize the coding requirements in this RS.

1.4 Overview

In addressing high rate equipment obsolescence and providing new enhanced services, TKUP will affect many areas of the SN. Figure 1-1 depicts the SN and its interfaces with elements external to the SN (NASA Integrated Services Network (NISN), Flight Dynamics Facility (FDF), Customer platform, and Customer Mission Operations Center (MOC)/Data Processing Facility (DPF)).

Figure 1-2 depicts the high level TKUP modifications to the STGT or WSGT and Figure 1-3 depicts the high level TKUP modifications to the GRGT. More specifically, the KSA High Data Rate (HDR) HWCI equipment that is a subset of the USS will be replaced and/or upgraded as shown in Figures 1-2 and 1-3. Figure 1-4 depicts the detailed TKUP modifications to the STGT or WSGT and Figure 1-5 depicts the detailed TKUP modifications to the GRGT. In addition, the Subsystem Controller (SSC) and switches comprising the KSA Control HWCI will be modified as required to support the TKUP upgrades and signal flows; KSA Control HWCI modifications will not alter the control and signal flows of the K-Band Single Access Forward (KSAF) equipment and other USS KSAR equipment that are not within the scope of the TKUP.

TKUP will also replace and upgrade the high rate digital switch of the High Rate Black Switch (HRBS) HWCI in the WSGT DIS and the high rate digital switch of the HRBS HWCI in the STGT DIS. In addition the GRGT LI high rate switch will be replaced and upgraded as shown in Figures 1-3 and 1-5. These changes will include the necessary modifications to the SSCs that provide the interface between the switch units and the DIS Automated Data Processing Equipment (ADPE).



- KSAR Hardware Configuration Items (HWCIs), Switching HWCIs, and Computer Software Configuration Items (CSCIs) to be upgraded or modified

Figure 1-1. SN and Interfaces With External Elements

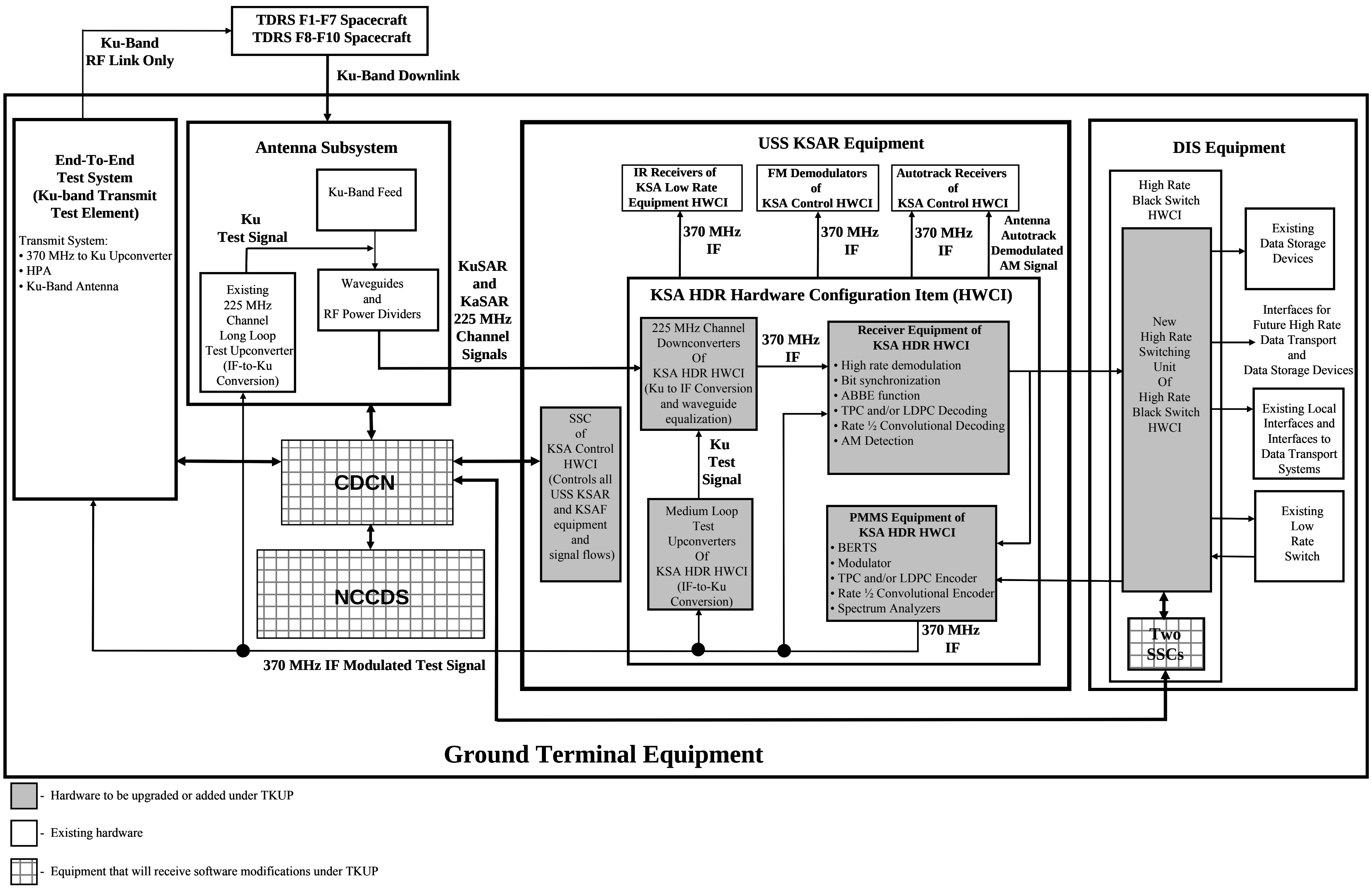


Figure 1-2. STGT or WSGT Architecture for TKUP 225 MHz Channel Return Services

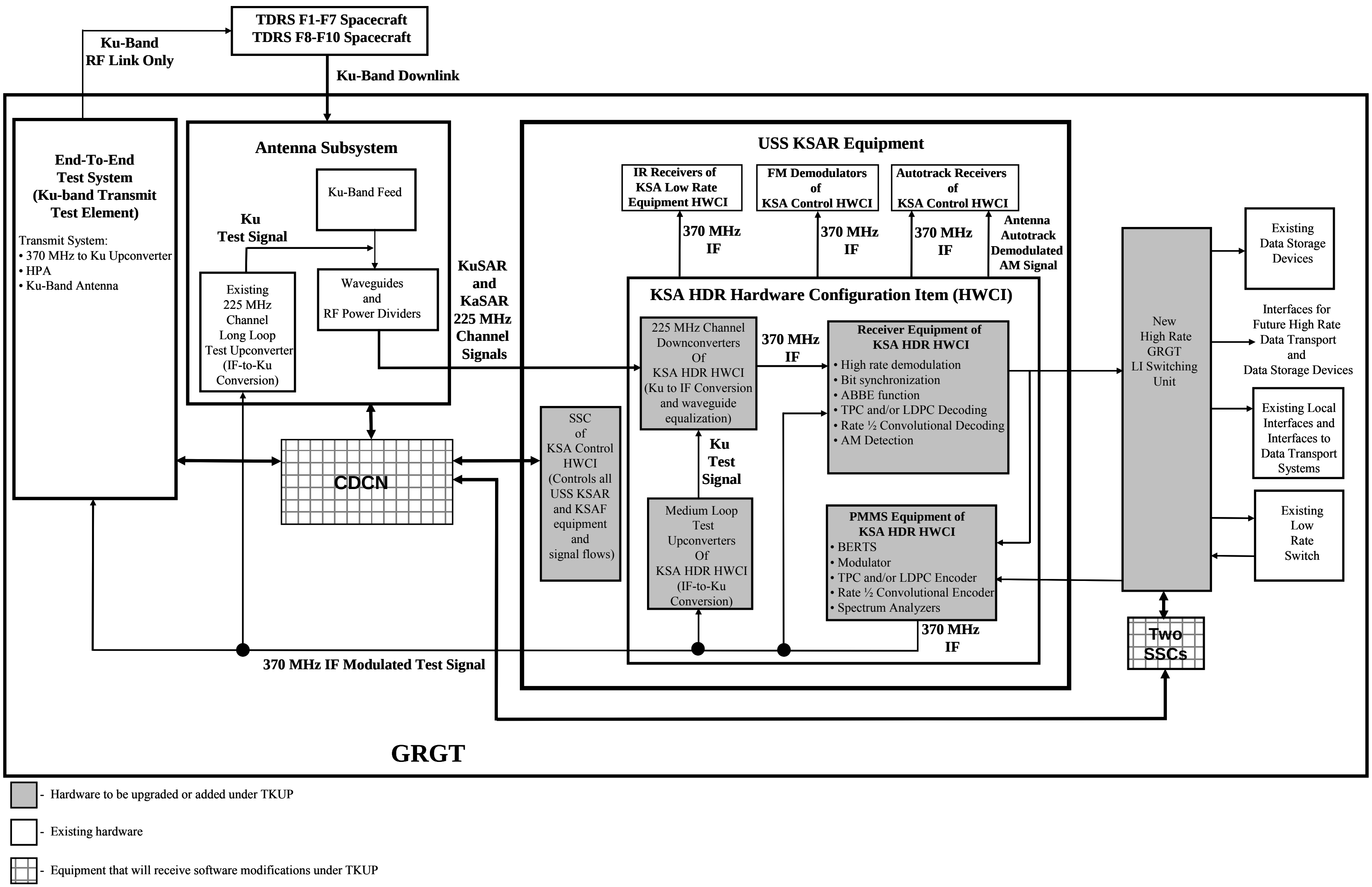


Figure 1-3. GRGT Architecture for TKUP 225 MHz Channel Return Services

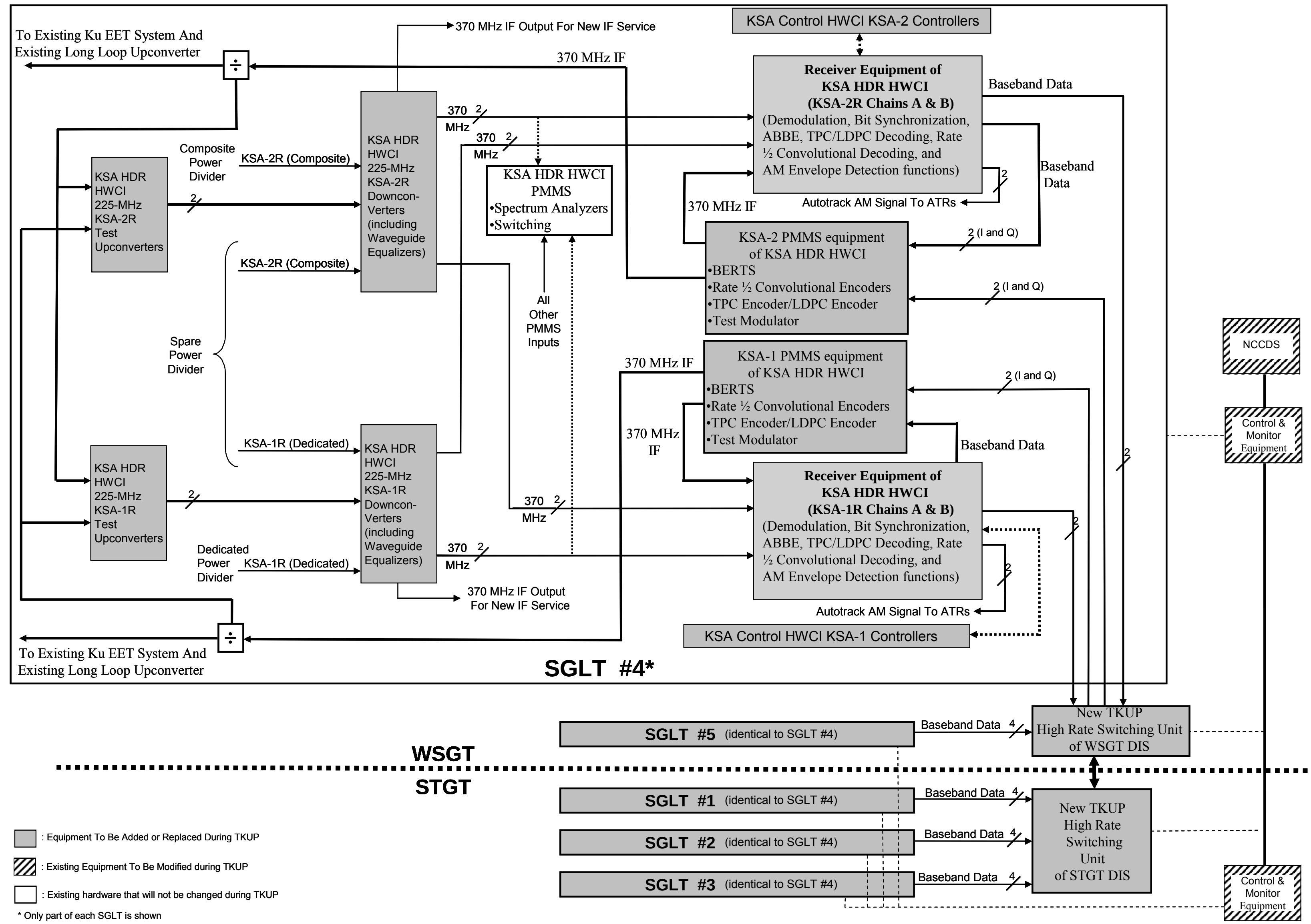
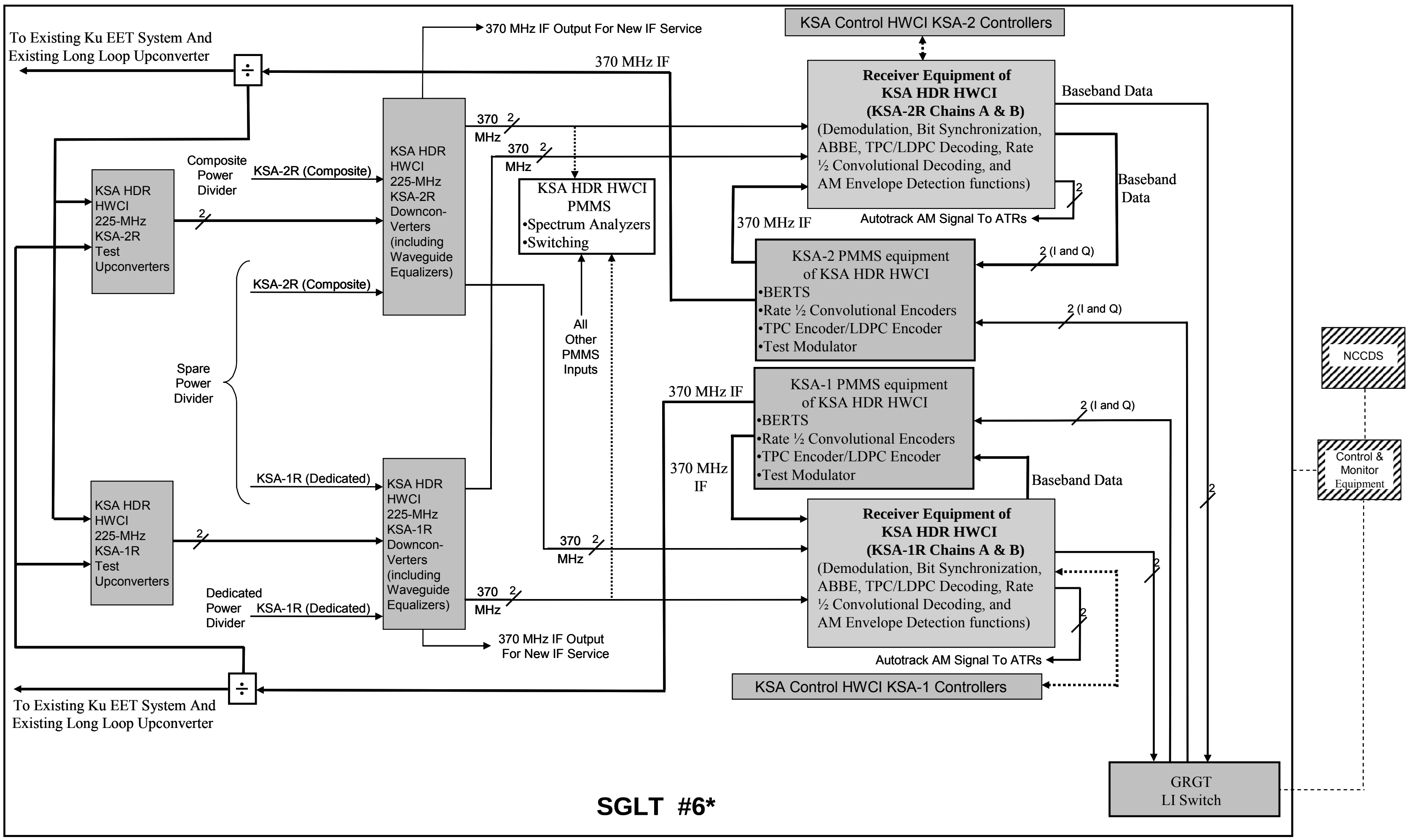


Figure 1-4. TKUP Equipment Replacement and Modification at WSC



: Equipment To Be Added or Replaced During TKUP

: Existing Equipment To Be Modified during TKUP

: Existing hardware that will not be changed during TKUP

* Only part of each SGLT is shown

Figure 1-5. TKUP Equipment Replacement and Modification at Guam

Software changes will be necessary to configure and monitor the status of the new hardware and to support the scheduling and real-time control and monitor of the new services. Figure 1-6 depicts the areas of the SN where software changes are needed.

1.5 KSA HDR HWCI Equipment

a. The HDR HWCI will contain two equipment groups, labeled KSA-1R and KSA-2R, for processing two K-Band radio frequency (RF) received signals as depicted in Figures 1-4 and 1-5. The two groups will be functionally identical except that the input signal to KSA-1R (dedicated) will be at 13,528.4 MHz (13,525.0 MHz for Space Network Interoperability Panel (SNIP)) while the input to KSA-2R (composite) will be at 13,928.4 MHz (13,925.0 MHz for SNIP).

b. Each equipment group will contain two independent and identical service chains, labeled A and B, consisting of downconversion equipment and receiver equipment.

   1. Each equipment group will be independently configurable and controllable.
   2. Each equipment group will be capable of configuring service chains identically and processing the same signal, with one chain designated as "On-line" and the other as "Standby" (See definitions below).

c. Each equipment group will contain one set of KSAR high rate performance measurement and monitoring system (PMMS) test equipment (PTE). It is not required that the PTE be redundant.

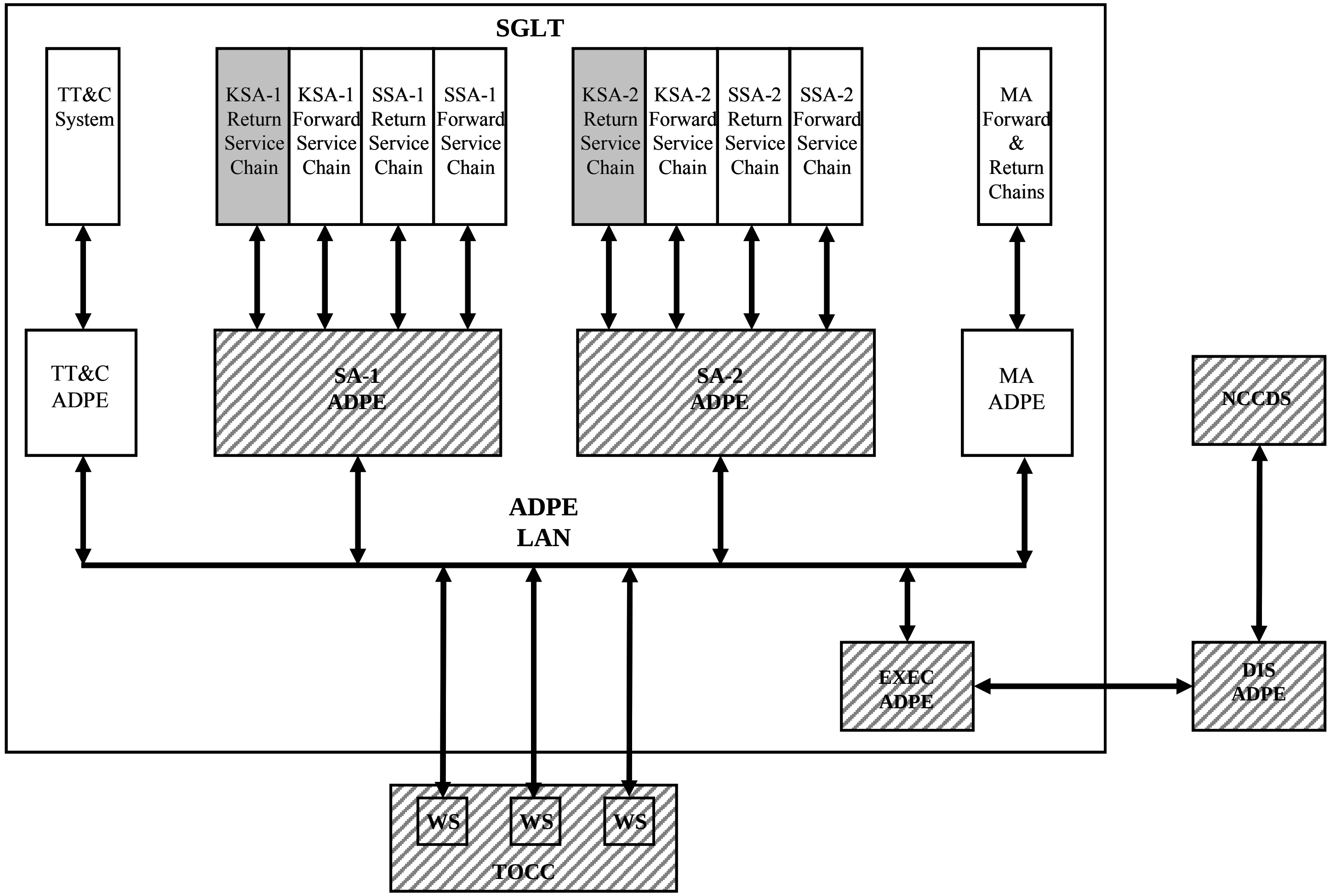
d. An IF switching capability will be provided to connect the KSA1 and KSA2 downconverters to the KSA1 and KSA2 receivers, respectively, or alternatively to cross-connect the KSA1 and KSA2 downconverters to the KSA2 and KSA1 receivers, respectively. The switch function will also provide the capability to route the output of the PTE modulator to either or both of the KSA1 and KSA2 receivers.

1.5.1 Receiver Equipment and Downconverters

The following USS KSAR data service equipment will be replaced or added in each Space-Ground Link Terminal (SGLT):

a. Receiver Equipment (Conducts demodulation, bit synchronization, Adaptive Baseband Equalizer (ABBE), Low Density Parity Check (LDPC) and/or Turbo Product Code (TPC) decoding, rate ½ convolutional decoding, and Amplitude Modulation (AM) envelope detection functions).

b. 225 MHz Channel Downconverters.



- Hardware to be upgraded under TKUP

- CSCI modifications only under TKUP

Figure 1-6. CSCIs Affected by TKUP

1.5.2 Performance Measuring and Monitoring System

The following PMMS KSAR equipment will be replaced or added in each of the five WSC SGLTs and the Guam SGLT:

a. Test Modulators.
b. TPC and/or LDPC Encoders.
c. Rate ½ Convolutional Encoders.
d. 225 MHz Channel Test Upconverters for medium loop testing.

1.6 KSA Control HWCI

The KSA1 and KSA2 SSCs and switching in the KSA Control HWCI shall be modified to support the control and signal flow of the new KSA HDR HWCI equipment. The KSA Control HWCI changes will be designed and implemented such that the capabilities and performance of HWCIs/subsystems outside the scope of TKUP are not impacted. (For example, HWCIs outside the scope of TKUP are the KSA Low Data Rate Equipment HWCI and USS RF Equipment Group HWCI).

1.7 High Rate Switching/Processing in Data Interface System Hardware Configuration Item

The new high rate switching unit will be a switch, router, or combination of switch and router. The new switching unit will provide room for new interfaces and for future WSC data distribution growth, but the switching unit will also maintain Emitter-Coupled Logic (ECL) data and clock interfaces for backward compatibility with current Customers that require ECL data and clock interfaces.

GRGT contains a high rate LI switch, controlled by the WSGT DIS CSCI, that will be replaced as shown in Figures 1-3 and 1-5.

1.8 Control and Display Computer Network, Network Control Center Data System, and Customer Scheduling Tools

Software modifications will be necessary for the following, as shown in Figure 1-6:

a. USS CSCI for the SA1 and SA2 ADPEs: The USS CSCI performs the control and monitoring of the USS hardware.
b. EXC CSCI: The EXC CSCI serves as the interface between the DIS CSCI and the USS and Tracking, Telemetry and Command (TTC) CSCIs to support the configuration and monitoring of the ground terminal hardware to support Customer services and the TDRS.
c. WKS CSCI: The WKS CSCI provides the human interface for operations of the ground terminal.

d. DIS CSCI: The DIS CSCI interfaces with the NCCDS to receive the Scheduling Messages (SHOs) and to exchange Operations Messages (OPMs) with the NCCDS.

e. NCCDS and Space Network Access System (SNAS): The NCCDS is the SN scheduling system. SNAS is the system that allows the Customer to interface with the NCCDS for scheduling and real-time control and monitoring of services. SNAS is not deployed yet, but is planned to be deployed prior to TKUP completion.

1.9 Document Organization

- Section 1, "Introduction" provides an introduction to the TKUP, the USS KSAR high rate equipment, and the High Rate Switches. It describes the background, purpose, scope, overview, document organization, and nomenclature.
- Section 2, "Documents List" provides a list of applicable and reference documents.
- Section 3, "Operations Concept" describes the concept of operations for TKUP within the SN.
- Section 4, "TKUP Technical Requirements" provides the KSA HDR HWCI Downconversion Requirements (Ku-to-370 MHz IF Processing), the KSA HDR HWCI High Rate Receiver Equipment Requirements (370 MHz IF-to-Baseband Processing), Antenna Autotracking requirements, Ku-Band Doppler requirements, high rate switching requirements, SN service management requirements, the interface requirements for the KSA HDR HWCI equipment, and the PMMS requirements.
- Section 5, "Maintenance Support Capabilities" provides the detailed maintenance requirements for all of the TKUP equipment.
- Section 6, "TKUP Reliability/Maintainability/Availability (RMA)" provides the detailed RMA requirements for the TKUP equipment.
- Section 7, "Design and Construction" provides the detailed TKUP physical, environmental, EMC, and electrical requirements.
- Section 8, "Security" provides the detailed security requirements for the TKUP equipment.
- Section 9, "TKUP Equipment Documentation" provides the TKUP documentation requirements.

1.10 Nomenclature

As used in this document, the following definitions apply:

Customer Platform. The platform carrying the Customer's receiving and/or transmitting equipment. The platform can be an orbiting spacecraft, suborbital platform (e.g., aircraft, balloon), or remote ground/sea platform (e.g., buoy).

Mission Operations Center / Data Processing Facility. The functions of the Customer Mission Operations Centers (MOCs) / Data Processing Facilities (DPF) for Ku-Band and

Ka-band services with the TKUP will be the same as existing S-band, Ku-band, and Ka-band (225 MHz channel) services.

Data Rate. From the sender's perspective, data rate is defined *after* any virtual channelization but *before* any encoding like rate ½ convolutional encoding, differential encoding or TPC, Attached Sync Marker (ASM) attachment, or TPC frame header. From the receiver's perspective, data rate is defined *after* any decoding like rate ½ convolutional, differential, or TPC or frame synchronization which a TPC frame includes, but *before* virtual channel extraction.

Symbol Rate. From the sender's perspective, symbol rate is the rate of symbols generated by the forward error correction encoder entering the modulator after any virtual channelization, encoding like rate ½ convolutional encoding, differential encoding, or TPC, and ASM attachment. From the receiver's perspective, symbol rate is defined *before* any decoding like rate ½ convolutional, differential, or TPC decoding, frame synchronization, or virtual channel extraction.

Receiver Equipment Chain. The equipment required to process a signal from RF to baseband. For the purposes of redundancy, the receiver equipment of the KSA HDR HWCI consists of two operationally identical equipment chains, Chain A and Chain B.

Online Mode. The mode defined as when an equipment chain (A or B) is designated and configured to provide operational support of a TDRSS service or services.

Standby Mode. The mode defined as when an equipment chain (A or B) is designated and configured to perform all operational functions in parallel to an online equipment group, but whose outputs are not utilized to deliver a customer service. In this mode, the equipment chain is monitored to determine its status and performance and is capable of assuming an online mode without significant loss of data.

Maintenance-Test Mode. The mode defined as when an equipment chain has been removed from operational service (Removed from Online or Standby) so that equipment problems can be troubleshot or testing can be performed.

Signal Presence. The new TKUP receive equipment will provide a "signal presence" indication signal and the recovered antenna autotrack AM envelope signal. The recovered AM envelope signal output and signal presence output will be sent to the KSAR autotrack receiver. The signal presence output will indicate whether or not the receive equipment is outputting a useable recovered AM envelope signal for antenna autotracking.

Doppler Frequency. The Doppler frequency is defined as the difference between the recovered carrier frequency and the reference frequency. For 1-way Doppler measurements, the Doppler reference frequency will be the NCCDS-provided customer transmit frequency. For two-way Doppler measurements, the Doppler reference frequency will be the forward transmit frequency multiplied by the Customer transponder turnaround ratio (1600/1469 at Ku-band).

SECTION 2. DOCUMENTS LIST

2.1 Applicable Documents

The following documents are part of this specification to the extent cited herein. The most recent version of these documents takes precedence. If there are conflicts between the listed documents and the requirements of this specification, the requirements of this specification take precedence. If no section number is shown when the document is cited, the whole document applies.

Document Number	Document Title
405-TDRS-RP-SY-001	*TDRS H,I,J Technical Requirements Specification*
405-TDRS-RP-SY-011	*White Sands Complex (WSC) Ground Terminal Requirements for the TDRS H,I,J Era*
450-SNUG	*Space Network (SN) Users' Guide, Mission Services Program Office*
452-ICD-SN/CSM	*ICD between the SN and Customers for Customer Service Management*
530-ICD-NCC-FDF/WSC	*Interface Control Document (ICD) between the Network Control Center (NCC)/Flight Dynamics Facility (FDF) and the White Sands Complex (WSC)*
530-RSD-WSC	*Requirements Specification for the White Sands Complex (WSC),* Section 5 and Section 13
EIA-390	*Racks, Panels, and Associated Equipment*
FCC Title 47	*Code of Federal Regulations (CFR) Title 47 (Telecommunications),* Part 15 (Radio Frequency Devices)
MIL-HDBK-217F	*Reliability Prediction Of Electronic Equipment, Department Of Defense*
NITR 2810-2	*Information Technology (IT) System Security Requirements*
NPD 2820.1	*NASA Software Policies*
NPG 2810.1	*Security of Information Technology: NASA Procedures and Guidelines*
NPG 8715.3	*NASA Safety Manual*

Document Number	Document Title
NPR 2810.1	*NASA Security of Information Technology*
S-323-P-5A	*Quality Assurance Requirements for Standard Industrial Equipment*
STDN 270.7	*GSFC Specification Grounding System Requirements for STDN Stations*
STDN SPEC-4	*GSFC General Requirements for STDN Electronic Equipment*
STDN SPEC-8	*GSFC Specification for Electronic Equipment Installation Materials*
WSC-PLN-0024	*Information Technology Systems Security Plan (ITSSP) for the White Sands Complex*
	TDRSS K-Band Upgrade Project Modulation and Coding Study, 19 May 2004, ITT Industries, John Wesdock, Chitra Patel

2.2 Reference Documents

The following documents are for reference only. The most recent version of these documents takes precedence.

Document Number	Document Title
452-PMP-TKUP	*Space Network Tracking and Data Relay Satellite System (TDRSS) K-Band Single Access Return (KSAR) Upgrade Project (TKUP) Project Management Plan*

SECTION 3. OPERATIONS CONCEPT

3.1 Operations Concept Goals

The operations concept goals of TKUP are as follows:

a. Backward Compatibility For Existing SN KSAR Services: All existing KSAR services will continue to be supported without any changes to systems external to the SN or their interfaces, with the following exceptions:

   1. Data Group (DG) 1 Mode 3 for high data rates will not be supported. However, DG1 Mode 3 will continue to be supported by the Integrated Receiver (IR) at data rates up to 6.0 Mbps on the Q-channel.
   2. Bi-phase data format for high data rates will not be supported.

NOTE

IR will continue to support bi-phase formats as follows:

- Binary Phase Shift Keying (BPSK) uncoded up to 3.0 Mbps
- BPSK coded up to 1.5 Mbps
- Dual channel Quadrature Phase Shift Keying (QPSK), uncoded channel up to 3.0 Mbps
- Dual channel QPSK, coded channel up to 1.5 Mbps
- Staggered QPSK (SQPSK), uncoded up to 5.0 Mbps
- SQPSK, coded up to 3.0 Mbps

b. Customer Reliance on Undocumented "Features" of the SN: Requirements have been specified on TKUP that define known undocumented characteristics or "features" of the existing SN system implementation that current SN Customers rely upon (e.g., data skew, service path delay and service path delay variation).

c. New KSAR Services: TKUP will implement the new services utilizing the existing SN operations concepts for existing KSAR services.

d. Minimize Impacts to Interfaces External to TKUP: Where TKUP will replace existing SN equipment, TKUP must ensure the existing interfaces are maintained to the extent practical.

3.2 Existing Customer Signal Formats

All current Customer platform signal formats will be supported by TKUP except as noted in Section 3.1. The unshaded blocks in Table 3-1 summarize the current KSAR signal formats that are processed by the KSAR high data rate receivers.

Also, the TKUP KSAR high rate receiver equipment will continue to support K-band Shuttle Return (KSHR) Mode 1 Channel 3 (I-Channel) demodulation. All other shuttle modes are supported by other KSAR equipment (including current low data rate IR that will not be altered during TKUP.)

TKUP will not affect current Customer platforms because TKUP will provide backward compatibility for current Customer signal formats.

3.3 New Customer Signal Formats and Data Rates

The shaded portions of Table 3-1 list the new bandwidth efficient modulation and coding signal formats and data rate capabilities that will be added under TKUP. TKUP along with the new bandwidth efficient signal designs will provide the following new SN capabilities/features:

a. Data Rates Up to 625 Mbps: TKUP will implement support for data rates up to 625 Mbps on the 225 MHz-wide channels. Customer EIRP requirements will be minimized across the new data rates by using TPC and/or LDPC-coded 8-PSK (8-ary Phase Shift Keying) (≤ 625 Mbps) and TPC and/or LDPC-coded SQPSK (≤ 410 Mbps) bandwidth efficient modulation and coding techniques with acceptable hardware complexity on the Customer platform. Only a single channel capability for TPC and/or LDPC signal formats will be supported.

b. Lower Customer EIRP Requirements For SQPSK at Current 150 Mbps - 300 Mbps Data Rates: Currently, the SN can support data rates greater than 150 Mbps up to 300 Mbps by using only uncoded SQPSK at relatively high EIRPs. TKUP will allow the SN to support the existing SQPSK modulation format and current data rates between 150 Mbps to 300 Mbps at significantly lower EIRP levels by using LDPC and/or TPC encoding rather than an uncoded SQPSK format.

c. Support Compressed Image Customers: TKUP will support the compressed image formats that NASA Customers will use with TKUP. Customers will require an image corruption rate of ≤ 1/100.

d. Support Non-Stacking Convolutional Encoding: Customer platforms will no longer be required to support parallel encoder stacking when operating with rate ½ convolutional coding at data rates above 10 Mbps. TKUP will also provide backward compatibility with Customers that use encoder stacking.

e. Support Any Data Link Layer Formats: TKUP will continue to support all Customers that use CCSDS, Department Of Defense (DOD), or Internet Protocol (IP) data link layers by placing LDPC and/or TPC on physical layer as currently done with rate ½ convolutional coding.

f. Customer Tracking Services: Customer tracking services will not be provided for the new services, but will continue to be provided for all existing Ku-band services. In the event that there is a need to provide customer tracking services in the future for the new services, TKUP will implement a frequency counter in the TKUP receiver to facilitate implementation of 1-way and/or 2-way Doppler measurements.

g. Autotrack for all Signal Formats: TKUP will support autotrack for all Ku-Band and Ka-Band signal formats including the new LDPC and/or TPC signal formats.

Table 3-1. KSAR High Data Rate Receiver Signal Formats and Data Rates (BPSK, QPSK, SQPSK, and 8-PSK) [1]

Coding Option	BPSK Data Rates	QPSK Data Rates	SQPSK Data Rates	8-PSK Data Rates
Uncoded, Single Channel	4 Mbps – 150 Mbps	N/A	8 Mbps – 300 Mbps	N/A
Uncoded, Dual Channel	N/A	8 Mbps – 300 Mbps[2]	8 Mbps – 300 Mbps	N/A
Rate ½ Convolutional Coding, Single Channel	2 Mbps – 75 Mbps	4 Mbps – 75 Mbps[3]	4 Mbps – 150 Mbps[3]	N/A
Rate ½ Convolutional Coding, Dual Channel	N/A	4 Mbps – 150 Mbps[4]	4 Mbps – 150 Mbps[4]	N/A
LDPC coded (8160,7136)	N/A	N/A	150 Mbps to 410 Mbps	150 Mbps to 625 Mbps
TPC coded				
(1) (128,120)x(128,120)	N/A	N/A	150 Mbps to 410 Mbps	150 Mbps to 625 Mbps
(2) (256,239)x(256,239)	N/A	N/A	150 Mbps to 410 Mbps	150 Mbps to 625 Mbps

NOTES

1. Shaded cells list new signal formats and data rates that will be implemented under TKUP. (This table does not include low rate capabilities supported by Integrated Receiver.)
2. TKUP added capability: Support dual channel uncoded QPSK with same data rates on I-channel and Q-channel.
3. For SQPSK, alternate I/Q encoded symbols and alternate I/Q data bits will be supported, but the data rate limit for alternate I/Q encoded symbols will be limited to the capability of available commercial off-the-shelf (COTS) single decoder chips, tentatively 75 Mbps. Also, for QPSK, TKUP added capability: Single channel QPSK with same symbol rates on I-channel and Q-channel channel, but using alternate I/Q Encoded Symbols only.
4. When using a dual channel configuration and only one channel is coded, then total data rate range will be 6 Mbps to 225 Mbps. Also, for QPSK, TKUP added capability: Support dual channel QPSK with same symbol rates on I-channel and Q-channel.

3.4 Features Not Added Under TKUP

a. Ka-Band Doppler support. TKUP will not implement a Ka-Band Doppler tracking service.

b. Ku-Band Doppler support for new signal designs with LDPC and/or TPC formats. TKUP will not implement a Doppler tracking service for the new Ku-Band signal formats that will use LDPC and/or TPC formats, but a frequency counter will be implemented in the new receiver so that a Doppler capability for the signal formats can be implemented, if needed, after TKUP is completed.

c. Reed Solomon Decoding at WSC. As currently done, Reed-Solomon decoding at the data link layer for high data rates will not be supported at WSC.

3.5 TDRSS KSAR Upgrade Project Transition Strategy

The SN is a 24 x 7 operation. It is imperative that the TKUP installation, testing, and transition activities do not perturb those day-to-day activities. The TKUP transition strategy should be designed to minimize impacts to SN service availability. Activities requiring system downtime require pre-coordination and approval using established SN procedures.

SECTION 4. TKUP TECHNICAL REQUIREMENTS

4.1 TKUP Functional System Requirements

a. TKUP shall replace the KSAR high rate equipment, as depicted in Figure 1-2, with new equipment that has added signal processing capabilities (bandwidth efficient modulation and coding), as specified in Table 3-1, at:
   1. STGT.
   2. WSGT.
   3. GRGT.

b. TKUP shall replace the following with new high rate switching units:
   1. The STGT DIS High Rate Digital Switch (HRDS) contained within the HRBS HWCI,
   2. The WSGT DIS HRDS contained within the HRBS HWCI, and
   3. The GRGT high rate LI switch function.

c. TKUP shall ensure the following are preserved so SN Customer and SN Operations are not impacted by the TKUP design:
   1. Existing capabilities, excluding DG1 Mode 3 and bi-phase data format for data rate > 6 Mbps, but DG1 Mode 3 and bi-phase will still be available when using the IR as detailed in section 3.1.
   2. TKUP external interfaces:
      a. Customer MOC
      b. Customer DPF
      c. FDF
      d. NISN

d. TKUP shall modify existing SN systems, excluding the User Planning System (UPS) and the Space Network Web Services Interface (SWSI), to support service management of the new services.

e. TKUP shall modify existing SN systems to:
   1. Control and status the new equipment and
   2. Support the new services

4.2 KSA HDR Downconversion Requirements (Ku-To-370 MHz IF)

This section provides the downconversion requirements for the KSA HDR HWCI. The KSA HDR HWCI will downconvert the RF signal received from the Antenna Subsystem to a 370 MHz IF signal. The downconverters of the KSA HDR HWCI are shown in Figure 1-2. The KSA HDR HWCI will distribute the 370 MHz IF signal to the receiver equipment of the KSA HDR HWCI, other USS KSAR equipment, and the IF Service Ports.

4.2.1 Downconverter Requirements

a. Each downconverter shall receive the Ku-Band 225 MHz-wide Ku-Band Single Access Return (KuSAR) and Ka-Band Single Access Return (KaSAR) RF input that has the signal characteristics listed in Table 4-1, from the Antenna Subsystem.

Table 4-1. RF Signal Characteristics At Antenna Subsystem Output

Parameter	Input Signal Characteristics
Center frequency	
- KuSA-1 (Dedicated)	13528.4 MHz ± 2.4 MHz
- KuSA-2 (Composite)	13928.4 MHz ± 2.4 MHz
- KaSA-1 (Dedicated)	
SNIP/SFCG	13525.0 MHz ± 2.4 MHz
TDRS-F8-F10	13528.4 MHz ± 2.4 MHz
- KaSA-2 (Composite)	
SNIP/SFCG	13925.0 MHz ± 2.4 MHz
TDRS F8-F10	13928.4 MHz ± 2.4 MHz
3-dB bandwidth of incoming signal	≤ 260 MHz (based on widest TDRS bandwidth[1])
Input signal level	
- KaSA-1 (Dedicated) (at output of Dedicated RF Power Divider; see Figure 1-4 above)	
Minimum	≥ -35 dBm when downconverter presents 50 ohm load
Maximum	≤ -15 dBm when downconverter presents 50 ohm load
- KaSA-2 (Composite) (at output of Composite RF Power Divider; see Figure 1-4 above)	
Minimum	≥ -40 dBm when downconverter presents 50 ohm load
Maximum	≤ -20 dBm when downconverter presents 50 ohm load
Input connectors required by downconverter	Four N-Type Female connectors (Two waveguide inputs and two spares)
NOTES	
1. 260 MHz is the widest measured TDRS bandwidth even though the allocated TDRS bandwidth is 225 MHz	

b. Each downconverter shall downconvert the RF input signal to a 370 MHz IF.

c. The downconverter shall perform automatic gain control (AGC) of the IF signal to a constant average power.

d. The downconverter shall perform fixed phase equalization of the incoming signal before or after the downconversion in order to compensate for waveguide distortions.

4.2.2 370 MHz IF Distribution Requirements

a. The KSA HDR HWCI shall distribute the 370 MHz IF signal output of the downconverter to the KSA HDR HWCI receiver equipment.

b. The KSA HDR HWCI shall distribute the 370 MHz IF signal output of the downconverter to the IF Output Ports.

c. The KSA HDR HWCI shall distribute the 370 MHz IF signal output of the downconverter to the following non-KSA HDR HWCI equipment:

1. Autotrack receivers.
2. Frequency Modulation (FM) demodulators.
3. Integrated receivers.

4.2.3 370 MHz IF Signal and Distortion Characteristics

a. The signal characteristics of the 370 MHz IF output signals shall be as specified in Table 4-2.

b. The contribution of the TKUP equipment to the distortion characteristics of the 370 MHz IF output signals shall not cause the distortion characteristics of the entire ground terminal infrastructure to exceed the values specified in Table 4-3.

4.2.4 Downconverter Local Oscillator

The downconverter local oscillator shall be synthesized from the Common Time and Frequency System (CTFS) 10 MHz reference.

4.2.5 Downconverter Phase Equalizer

a. The downconverter equipment shall have the capability to phase equalize the KuSAR or KaSAR signals, either before or after the downconverter process, to compensate for the parabolic phase induced by the waveguide.

b. After phase equalization, the phase nonlinearity shall be as specified in Table 4-3, Phase Nonlinearity parameter.

4.2.6 Gain Distortion Requirements

a. The gain flatness distortions shall be as specified in Table 4-3, Gain Flatness parameter.

b. The gain slope distortions shall be as specified in Table 4-3, Gain Slope parameter.

Table 4-2. Signal Characteristics of 370 MHz IF Signal[1]

4.2.3 a	Parameter	Requirement
(1)	Center frequency	370 MHz
(2)	Bandwidth	≥ 350 MHz (3-dB)
(3)	Output level	-10 dBm ±3 dB into 50 ohm load[2] (-10 dBm is typical level of current inputs of equipment as defined in Section 4.8)
(4)	Output VSWR	≤ 1.3:1 into 50Ω load, ±80 MHz from center frequency
NOTES		
1. Additional interface requirements are specified in Section 4.8. 2. Paragraph 4.2.1c provides the "short term" AGC requirement for the downconverter power level.		

Table 4-3. Signal Distortions Requirements for Ground Terminal Infrastructure

4.2.3 b	Parameter	Requirement
(1)	Gain Flatness	0.6 dB peak-to-peak over ±80 MHz about the center frequency
(2)	Gain Slope	≤ 0.1 dB/MHz over ±80 MHz about the center frequency
(3)	Phase nonlinearity	6° peak-to-peak over ±80 MHz about the center frequency
(4)	Phase Noise (SSB phase noise in 1 Hz BW)	-80 dBc maximum at 10^{-1} Hz to 10^{0} Hz offset -105 dBc maximum at 10^{0} Hz to 10^{1} Hz offset -120 dBc maximum at 10^{1} Hz to 10^{2} Hz offset -125 dBc maximum at 10^{2} Hz to 10^{3} Hz offset -140 dBc maximum at 10^{3} Hz to 10^{4} Hz offset -155 dBc maximum at 10^{4} Hz to 10^{5} Hz offset (Phase noise specified using directly measurable units rather than degrees RMS)
(5)	In-band spurious outputs, where bandwidth is as stated in Table 4-2.	≥ 30 dB below desired signal (sum of all spurious signals) ≥ 40 dB below desired signal (individual spurious signals)

4.2.7 Performance in Presence of Pulsed RF Interference

a. Damage and Degradation. The pulsed radio frequency interference (RFI), with characteristics as listed in Table 4-4, shall not cause damage or cumulative degradation to the downconverter or any TKUP receiver equipment.

b. Pulse Spreading. The downconverter shall not extend the effect of a RFI pulse, with characteristics as listed in Table 4-4, by more than 100 ns when measured at the IF Output Port.

Table 4-4. Pulsed RFI Characteristics

Parameter	Characteristic
Pulse width	≤ 1 μsec
Pulse amplitude	≤ 10 dB above average received power
Duty cycle	≤ 1%

4.2.8 Downconverter Control & Monitor

a. The downconverter equipment of the KSA HDR HWCI shall be controllable via front panel controls.

b. The downconverter equipment of the KSA HDR HWCI shall be controllable remotely via the Control and Display Computer Network (CDCN).

c. The downconverter equipment of the KSA HDR HWCI shall provide equipment and performance status data to the CDCN as commanded, at a minimum rate of once per second.

d. The downconverter equipment of the KSA HDR HWCI shall be configurable in accordance with commands received from front panel controls or CDCN as follows as a minimum:

1. Input Selected
2. Remote/Local
3. AGC selected
4. Operational Modes (CDCN only):
    a. Online
    b. Standby
    c. Maintenance-Test Mode
5. Frequency (TDRS or SNIP)
6. Waveguide Equalizer Select (SGLT-1, SGLT-2, SGLT-3, bypass)

e. The downconverter equipment shall provide equipment configuration status, upon request to the CDCN.
    1. Input Selected
    2. Remote/Local
    3. AGC status
    4. Power Supply Status
    5. Summary Fault
    6. Status of Phase Lock to 10 MHz Reference
    7. Operational Modes
        a. Online
        b. Standby
        c. Maintenance-Test Mode
    8. Frequency Select (TDRS or SNIP)
    9. Waveguide Equalizer Select (SGLT-1, SGLT-2, SGLT-3, bypass)

f. The downconverter equipment shall provide self-testing support.

g. The downconverter equipment shall support maintenance commands to perform self test for the purpose of isolating any defective Line Replaceable Units (LRUs).
    1. When commanded to fault isolate, the downconverter equipment shall identify any defective LRUs.
    2. Upon command, the downconverter equipment shall report the identification (ID) number of the faulty LRU to the CDCN for at least 90% of LRU faults.
    3. Upon command, the downconverter equipment shall report the ID number of the faulty LRU to the CDCN with a maximum false detect probability of 5%.

4.3 KSA HDR HWCI High Rate Receiver Equipment Requirements (370 MHz IF-To-Baseband)

This section provides the 370 MHz-to-baseband processing requirements for the receiver equipment of the KSA HDR HWCI. The receiver equipment is a part of the KSA HDR HWCI as shown in Figure 1-2 and receives the 370 MHz IF signal from the downconverter of the KSA HDR HWCI (Section 4.2 describes the downconverter requirements). The receiver equipment will conduct demodulation, bit synchronization, baseband equalization, and decoding. The receiver equipment may be contained in one or multiple physical units. This section includes the requirements for the modulation and coding signal formats used for the 225 MHz channel high rate data services (2 Mbps to 625 Mbps).

4.3.1 High Level Signal Processing Requirements

a. The receiver equipment shall demodulate the HDR 370 MHz $\pm$ 2.4 MHz IF signal to baseband.

b. The receiver equipment shall resolve data and channel ambiguity, as applicable.

c. The receiver equipment shall perform symbol synchronization on the demodulator outputs.

d. The receiver equipment shall perform adaptive baseband equalization (ABBE) of the demodulator outputs as necessary to meet performance requirements.

e. The receiver equipment shall provide the option to perform data detection (i.e., hard decision data) using the equalizer output signal or the symbol synchronizer output signal.

f. For convolutionally encoded signals, the receiver equipment shall perform Viterbi decoding using the detected data.

g. For TPC and/or LDPC encoded signals, the receiver equipment shall perform TPC and/or LDPC decoding using the detected data.

h. For differentially formatted signals, the receiver equipment shall perform differential decoding (data format conversion) of the detected data.

i. For single data channel configurations, the receiver equipment shall multiplex the I and Q data into a single channel stream.

j. The receiver equipment shall provide output data to the KSA Control HWCI switches.

k. The receiver equipment shall clamp the data output (I and Q channel independently for dual data operation) to a logical one when there is a “bit synchronizer lock” loss indication.

l. The receiver equipment shall continue providing clock when the data is clamped to a logical one.

m. The receiver equipment shall provide antenna autotracking AM envelope detection functions at a minimum for TPC and/or LDPC signal formats including a “signal presence” indicator.

4.3.2 KSA Return Signal Formats (Modulation, Coding, and Data Rate Parameters)

a. The receiver equipment contained within the KSA HDR HWCI shall be capable of supporting an input signal with the parameters defined in Table 4-5.

b. The receiver equipment shall support the following service configurations whose parameter values are defined in Table 4-5:

   1. Uncoded BPSK, Single Channel Configuration
   2. Coded BPSK, Single Channel Configuration
   3. Uncoded QPSK, Dual Channel Configuration:
      a. Support equal data rates on I & Q Channels.
      b. Support unequal data rates on I & Q channels.
      c. Support I:Q power ratio of 1:1 with ±0.4 dB accuracy.
      d. Support I:Q power ratio of 4:1 with ±0.4 dB accuracy.
      e. When using 4:1 power ratio, I-channel shall contain a higher data rate.

Table 4-5. Receiver Equipment Signal Parameter Requirements

4.3.2 a	Parameter	(1) BPSK Requirements	(2) QPSK Requirements	(3) SQPSK Requirements	(4) 8-PSK Requirements
(a)	I:Q power ratio	N/A	1:1 and 4:1	1:1 and 4:1	N/A
(b)	Data format	NRZ-L,M,S	NRZ-L,M,S	NRZ-L,M,S[1]	NRZ-L
(c)	Total data rate[2]				
(c1)	Uncoded, Single Channel	4 Mbps – 150 Mbps	N/A	8 Mbps – 300 Mbps	N/A
(c2)	Uncoded, Dual Channel	N/A	8 Mbps – 300 Mbps[3]	8 Mbps – 300 Mbps	N/A
(c3)	Rate ½ Convolutional Coding, Single Channel	2 Mbps – 75 Mbps	4 Mbps – 75 Mbps[4]	4 Mbps – 150 Mbps[4]	N/A
(c4)	Rate ½ Convolutional Coding, Dual Channel	N/A	4 Mbps – 150 Mbps[5,6]	4 Mbps – 150 Mbps[5]	N/A
(c5)	LDPC coded (8160,7136) (TBD)	N/A	N/A	150 Mbps to 410 Mbps	150 Mbps to 625 Mbps
(c6)	TPC coded (TBD)				
(c6a)	(128,120)x(128,120)	N/A	N/A	150 Mbps to 410 Mbps	150 Mbps to 625 Mbps
(c6b)	(256,239)x(256,239)	N/A	N/A	150 Mbps to 410 Mbps	150 Mbps to 625 Mbps

NOTES

1. Exceptions include: For TPC and LDPC modes, only NRZ-L applies. For uncoded SQPSK, single channel configuration and rate ½ SQPSK, single channel configuration (alternate data bits), only NRZ-M and NRZ-S apply.
2. Data rate is measured prior to encoding.
3. TKUP added capability: Support dual channel uncoded QPSK with same data rates on I-channel and Q-channel.
4. For SQPSK, alternate I/Q encoded symbols and alternate I/Q data bits will be supported, but the data rate limit for alternate I/Q encoded symbols will be limited to the capability of available commercial off-the-shelf (COTS) single decoder chips, tentatively 75 Mbps. Also, for QPSK, TKUP added capability: Single channel QPSK with same symbol rates on I-channel and Q-channel channel, but using alternate I/Q Encoded Symbols only.
5. When using a dual channel configuration and only one channel is coded, then total data rate range will be 6 Mbps to 225 Mbps. Also, for QPSK, TKUP added capability: Support dual channel QPSK with same symbol rates on I-channel and Q-channel.
6. These QPSK parameters also apply to I-channel demodulation of QDSB signal for KSHR Mode 1 whose characteristics are specified in paragraph 4.3.2. For QDSB, data rates down to 2 Mbps on the I-channel only will be supported.

f. When using 4:1 power ratio with the data rate on the I-channel exceeding 70% of the maximum allowable data rate of the channel, the Q-channel data rate shall not exceed 40% of the maximum allowable data rate on the Q-channel.

4. Coded QPSK, Dual Channel Configuration, coding on both channels:
    a. Support equal data rates on I & Q Channels.
    b. Support unequal data rates on I & Q channels.
    c. Support I:Q power ratio of 1:1 with ±0.4 dB accuracy.
    d. Support I:Q power ratio of 4:1 with ±0.4 dB accuracy.
    e. When using 4:1 power ratio, I-channel shall contain a higher data rate.
    f. When using 4:1 power ratio with the data rate on the I-channel exceeding 70% of the maximum allowable data rate of the channel, the Q-channel data rate shall not exceed 40% of the maximum allowable data rate on the Q-channel.
5. Coded QPSK, Dual Channel Configuration, coding on only one channel:
    a. Support equal symbol rates on I & Q Channels.
    b. Support unequal symbol rates on I & Q channels.
    c. Support I:Q power ratio of 1:1 with ±0.4 dB accuracy.
    d. Support I:Q power ratio of 4:1 with ±0.4 dB accuracy.
    e. When using 4:1 power ratio, I-channel shall contain a higher symbol rate.
    f. When using 4:1 power ratio with the symbol rate on the I-channel exceeding 70% of the maximum allowable symbol rate of the channel, the Q-channel symbol rate shall not exceed 40% of the maximum allowable symbol rate on that Q-channel.
    g. Receiver equipment shall support encoding on I-channel or Q-channel.
6. Rate ½ Coded QPSK, Single Channel Configuration (Alternate I/Q Symbols):
    a. Support alternate I/Q encoded symbols without multiple encoders in parallel (encoder stacking).
    b. Support G1 symbols on I-channel and G2 symbols on Q-channel.
7. Uncoded SQPSK, Dual Channel Configuration:
    a. Support only equal data rates on I & Q channels.
    b. Support I:Q power ratio of 1:1 with ±0.4 dB accuracy.
    c. Support I:Q power ratio of 4:1 with ±0.4 dB accuracy.
8. Uncoded SQPSK, Single Channel Configuration.
9. Coded SQPSK, Dual Channel Configuration, coding on both channels.
    a. Support only equal data rates on I & Q channels.
    b. Support I:Q power ratio of 1:1 with ±0.4 dB accuracy.
    c. Support I:Q power ratio of 4:1 with ±0.4 dB accuracy.

10. Coded SQPSK, Dual Channel Configuration, Coding on only one channel:
    a. Support only equal symbol rates on I & Q channels.
    b. Support I:Q power ratio of 1:1 with ±0.4 dB accuracy
    c. Support I:Q power ratio of 4:1 with ±0.4 dB accuracy.
    d. Receiver equipment shall support encoding on I-channel or Q-channel.
11. Rate ½ Coded SQPSK, Single Channel Configuration (Alternate I/Q Symbols):
    a. Support alternate I/Q encoded symbols without multiple encoders in parallel (encoder stacking).
    b. Support G1 symbols on I-channel and G2 symbols on Q-channel.
12. Rate ½ Coded SQPSK, Single Channel Configuration (Alternate Data Bits):
    a. Support Alternate Data Bits without multiple encoders in parallel.
    b. Support Alternate Data Bits with multiple encoders in parallel (encoder stacking).
13. SQPSK, Single Channel Configuration with LDPC and/or TPC (TBD).
14. 8-PSK, Single Channel Configuration with LDPC and/or TPC (TBD).
15. KSHR Mode 1 Configuration, Quadrature Double Sideband (QDSB):
    a. The receiver equipment shall only demodulate the data on the I-channel which can be between 2 Mbps and 50 Mbps.
    b. The receiver equipment shall support an I-channel signal that is always encoded with five parallel encoders.
16. AM Demodulation For Antenna Autotrack for TPC/LDPC signal formats:
    a. The receiver equipment shall AM demodulate the 370 MHz IF signal when it contains the AM modulation characteristics as specified in Appendix A.
    b. The receiver equipment shall output the recovered AM signal to the Autotrack Receiver (ATR).

NOTE

Appendix C provides additional graphical depictions of all these service configurations.

4.3.3 Receiver System Signal Acquisition

This section specifies the high rate receiver equipment acquisition requirements for all signal formats.

4.3.3.1 Acquisition Time Requirement for All Signal Formats Except For K-Band Shuttle Return Mode 1

For the configurations defined in 4.3.2.b.1-14 and under the following conditions, the high rate receiver equipment shall be capable of conducting carrier acquisition, bit acquisition on each channel, and decoder acquisition on the Customer platform signal in ≤1 second with a probability ≥0.9 when the Customer center frequency uncertainty is ≤±21 kHz.

Conditions:

- C/N_o at SGLT Antenna Subsystem output ≥ 70 dB-Hz or that required to achieve E_b/N_o commensurate with the theoretical plus implementation loss values that are specified in Section 4.3.9 for a BER of 10^{-5}, whichever is greater.
- The Customer frequency dynamics as defined in Section 4.3.10.
- The bit transition density values as specified in Section 4.3.5.1.

4.3.3.2 Acquisition Time Requirement for New Signal Formats Only

For the configurations defined in 4.3.2.b.13-14 and under the following conditions, the high rate receiver equipment shall be capable of conducting carrier acquisition, bit acquisition on each channel, and decoder acquisition on the Customer platform signal in ≤3 second with a probability ≥0.9 when the Customer center frequency uncertainty is ≤±54 kHz.

Conditions:

- C/N_o at SGLT Antenna Subsystem output required to achieve E_b/N_o commensurate with the theoretical plus implementation loss values that are specified in Section 4.3.9 for a BER of 10^{-5}.
- The Customer frequency dynamics as defined in Section 4.3.10.
- The bit transition density values as specified in Section 4.3.5.1.

4.3.3.3 Acquisition Time Requirement For K-Band Shuttle Return Mode 1

For the KSHR Mode 1 configuration defined in 4.3.2.b.15 and under the following conditions, the high rate receiver equipment shall be capable of conducting carrier acquisition, bit acquisition on each channel, and decoder acquisition on the Customer platform signal in ≤ 1.0 second with a probability ≥0.9 when the Customer center frequency uncertainty is ≤ ±500 kHz.

Conditions:

- C/N_o at SGLT Antenna Subsystem Output ≥ 89.4 dB-Hz which is total C/N_o.
- The Customer frequency dynamics as defined in Section 4.3.10.
- The bit transition density values as specified in Section 4.3.5.1.

4.3.3.4 Loss of Lock Recovery Requirements

a. The receiver equipment shall be capable of detecting a loss of carrier lock.
b. The receiver equipment shall be capable of detecting bit lock on any channel.
c. The receiver equipment shall be capable of detecting decoder lock.
d. When the receive equipment detects any loss of lock, as specified above, it shall automatically initiate reacquisition of the appropriate synchronization loops, using pre-drop-lock data as an aid in the case of carrier loss of lock.

e. The receiver equipment shall be capable of recovering from a loss of lock when the signal outage ends with a reacquisition time of ≤ 0.5 seconds.

f. If re-acquisition fails, the receiver equipment shall automatically revert to the initial acquisition process.

4.3.4 Receiver System Carrier Tracking

4.3.4.1 Carrier Tracking Loop Bandwidth

a. The high rate receiver equipment shall support multiple carrier tracking loop bandwidths that include, but are not necessarily limited to, the following:

1. 340 Hz
2. 1200 Hz
3. 4500 Hz
4. 14 kHz
5. 100 kHz

b. The high rate receiver equipment shall autonomously select a carrier loop bandwidth such that all performance specifications shall be met when the signal conforms to all applicable constraints.

c. The high rate receiver equipment shall provide the capability to override the autonomously selected carrier loop bandwidth selection via the control and status interface.

d. The high rate receiver equipment shall provide the capability to override the autonomously selected carrier loop bandwidth selection via the local (front panel) interface.

4.3.4.2 Cycle Slips

The high rate receiver equipment shall be capable of providing a mean time-to-cycle-slip in carrier tracking that is ≥90 minutes for a C/N_o at a level that is greater than or equal to a level that is 3 dB less than that required for a BER of 10^{-5} at the output of the high rate receiver equipment.

4.3.5 Receiver System Bit Synchronization

4.3.5.1 Bit Transition Density on Each Channel

The high rate receiver equipment shall be capable of achieving and maintaining clock (bit) synchronization for the following constraints:

- Number of bit transitions: ≥128 within any sequence of 512 bits.
- Number of consecutive bits without a transition: ≤64.

NOTE

A “bit” is defined as the data unit on each individual I and Q channel after demodulation (For example, see demodulator outputs in Figures of Appendix C.)

4.3.5.2 Quantization Requirement

The bit synchronizer on each channel shall support 4-bit or more quantization output.

4.3.5.3 Bit Synchronizer Tracking Loops

a. The high rate receiver equipment shall have independent I & Q bit synchronizer tracking loops.

b. The high rate receiver equipment shall support multiple bit synchronizer loop bandwidths that include, but are not necessarily limited to, the following:

    1. 0.055% of the channel bit rate
    2. 0.1% of the channel bit rate
    3. 0.75% of the channel bit rate
    4. 1.0% of the channel bit rate

c. The high rate receiver equipment shall autonomously select a bit synchronizer loop bandwidth such that all performance specifications shall be met when the signal conforms to all applicable constraints.

d. The high rate receiver equipment shall provide the capability to override the autonomously selected bit synchronizer loop bandwidth selection via the control and status interface.

e. The high rate receiver equipment shall provide the capability to override the autonomously selected bit synchronizer loop bandwidth selection via the local (front panel) interface.

4.3.5.4 Bit Slips

4.3.5.4.1 Normal Transition Density

For the bit transition density and C/N_o defined below, the receiver equipment shall be capable of providing a mean time between bit slips of ≥ 90 minutes for the I and Q channels when bit slip is caused by a cycle slip in the bit recovery loop:

- Bit Transition Density. NRZ symbols: ≥40%.
- C/N_o. The C/N_o is at a level that is greater than or equal to a level that produces a BER of 10^{-5} at the output of the receiver equipment.

4.3.5.4.2 Low Transition Density

For the bit transition density and C/N_o defined below, the high rate receiver equipment shall be capable of providing a mean time between bit slips of ≥ 90 minutes for the I and Q channels when bit slip is caused by a cycle slip in the bit recovery loop:

- Bit Transition Density. NRZ symbols: ≥25% and <40%.
- C/N_o. The C/N_o is at a level that is greater than or equal to a level that is 1 dB greater than the level required for a BER of 10^{-5} at the output of the high rate receiver equipment.

4.3.6 Adaptive Baseband Equalizer

An ABBE, if needed to meet the BER performance requirements in section 4.3.9, shall be used:

a. Automatically compensate for intersymbol interference and I/Q crosstalk introduced by the Customer-TDRS-Ground Terminal channel.
b. The ABBE shall support 4-bit or more quantization input.
c. The ABBE shall support 5-bit or more internal mathematics.
d. The ABBE shall support 4-bit output quantization.

4.3.7 Decoding Requirements

4.3.7.1 Rate ½ Convolutional Decoding

a. The receiver system shall support multiple encoders (i.e., encoder stacking).
b. The receiver system shall support a configuration with only a single encoder on each channel (i.e., no encoder stacking).
c. The receiver system shall support a single encoder with the encoding conducted before the data is split into I-channel and Q-channel streams (i.e., single channel with Alternate I/Q Encoded Symbols).
d. The receiver system shall support the rate ½ convolutional coding configurations listed in Table 4-6.

Table 4-6. 225-MHz Channel Convolutional Coding Configurations: BPSK, QPSK, and SQPSK

4.3.7.1 d	Customer Configuration	(i) BPSK	(ii) QPSK	(iii) SQPSK
(1)	Single data channel convolution coding	X	X[2]	X[1]
(2)	Dual independent data channels	N/A	X[3]	X[3]
NOTES				
1. For SQPSK, data is encoded prior to I- and Q-Channel separation (alternate I/Q encoded symbols) or I- and Q-Channel data is individually convolutionally encoded after channel separation (alternate data bits). 2. For QPSK, only the “alternate encoded symbols” method is used for single channel operations. 3. I- and Q-channel data is individually convolutionally encoded.				

e. The high rate receiver equipment contained within the KSA HDR HWCI shall be capable of supporting the convolutional coding configurations specified below:

NOTE

The convolutional code defined below is KSAR Code 1 in Appendix K to 405-TDRS-RP-SY-011. It is identical to the code recommended in CCSDS 101.0-B-4, except that the CCSDS (1) always inverts the G2 symbols, and (2) makes no recommendations regarding the use of parallel encoders.

1. Rate (R): R = ½.
2. Constraint Length (K): K = 7.
3. Generator Polynomials:
    a. G1 = 1111001.
    b. G2 = 1011011.
4. G1 and G2 Symbol Timing: Symbols generated from G1 shall precede symbols generated from G2 relative to the data bit period.
5. G2 Inversion: Symbols generated from G2 shall be either true or complemented.

4.3.7.1.1 BPSK (2 Mbps to 75 Mbps)

A single encoder or encoder stacking shall be used with BPSK as follows:

a. Each encoder shall consist of “n” branch encoders in parallel. (450-SNUG, Revision 8, defines the configuration of the parallel encoders)
b. The Customer specifies the desired number of encoders, however:
    1. the minimum number of encoders shall be one (n=1), and
    2. the maximum number of encoders shall be eight (n=8)

4.3.7.1.2 Single Channel QPSK and SQPSK (4 Mbps to 75 Mbps) (Alternate I/Q Symbols)

Only a single encoder shall be used when using alternate I/Q symbols with QPSK and SQPSK.

4.3.7.1.3 Single Channel Staggered Quadrature Phase Shift Keying (4 Mbps to 150 Mbps) (Alternate Data Bits)

A single encoder on each channel or encoder stacking on each channel shall be used as follows:

a. Each encoder shall consist of “n” branch encoders in parallel. (450-SNUG, Revision 8, defines the configuration of the parallel encoders.)
b. The composite serial symbol output from the encoder shall consist of the branch encoder output symbols interleaved every n^{th} symbol.
c. The Customer specifies the desired number of encoders, however:
    1. the minimum number of encoders on each channel shall be one (n=1), and
    2. the maximum number of encoders on each channel shall be eight (n=8)

4.3.7.1.4 Dual Channel QPSK and SQPSK (4 Mbps to 150 Mbps)

A single encoder on each channel or encoder stacking on each channel shall be used as follows for configurations listed in 4.3.2.b.4, 4.3.2.b.5, 4.3.2.b.9, and 4.3.2.b.10:

a. Each encoder shall consist of “n” branch encoders in parallel. (450-SNUG, Revision 8, defines the configuration of the parallel encoders.)

b. The composite serial symbol output from the encoder shall consist of the branch encoder output symbols interleaved every n^{th} symbol.

c. The Customer specifies the desired number of encoders, however:

   1. the minimum number of encoders on each channel shall be one (n=1), and

   2. the maximum number of encoders on each channel shall be eight (n=8)

4.3.7.2 Low Density Parity Check Decoding (TBD)

The high rate receiver equipment contained within the KSA HDR HWCI shall be capable of supporting the following LDPC decoding functions for all applicable data rates as specified in Table 4-5:

a. Perform real-time decoding of a signal encoded with an (8160,7136) LDPC of generator polynomials as follows:

   1. (TBD):

b. Perform decoding as specified in Section 4.3.9 and (TBD-LDPC reference document).

NOTE

The following were used during NASA TKUP Modulation and Coding simulations or are recommended capabilities:

- Support a 4-bit quantized soft metric decoder input format.
- Support 5-bit or greater quantization in the decoder soft-input-soft output (SISO) calculations.
- Support variable clip levels.
- Support adjustable decoder feedback weights.
- Support five or more full decoding iterations.
- Support I/Q soft decision to soft metric conversion which is equivalent to or nearly equivalent to Log-Likelihood Ratio (LLR) mapping.
- For 8-PSK service, shall perform real-time I/Q soft decision to bit soft metric conversion.
- Shall support helical deinterleaving.
- Shall support multiple frame synchronization techniques such as freewheeling timing, frame synch header location timing and combinations of both.

- Shall support variable header sensitivity (i.e., only 95% or 90% of the frame synch bits must be observed to be correct to declare a beginning of a frame).
- Shall support resolution of phase ambiguity for QPSK and 8-PSK which may or may not require sending reacquisition or phase step commands to the receiver.
- Shall support a status interface which provides current configuration information and decoder lock status.

4.3.7.3 Turbo Product Code Decoding (TBD)

The high rate receiver equipment contained within the KSA HDR HWCI shall be capable of supporting the following TPC decoding functions for all applicable data rates as specified in Table 4-5:

a. Perform real-time decoding of a signal encoded with a (128,120)x(128,120) TPC of generator polynomials as follows:

   1. (TBD)

b. Perform real-time decoding of a signal encoded with a (256,239)x(256,239) TPC of generator polynomials as specified below:

   1. (TBD)

c. Perform decoding as specified in Section 4.3.9 and (TBD-TPC reference document).

NOTE

The following were used during NASA TKUP Modulation and Coding simulations or are recommended capabilities:

- Support a 4-bit quantized soft metric decoder input format.
- Support 5-bit or greater quantization in the decoder soft-input-soft output (SISO) calculations.
- Support variable clip levels.
- Support adjustable decoder feedback weights.
- Support five or more full decoding iterations.
- Support I/Q soft decision to soft metric conversion which is equivalent to or nearly equivalent to Log-Likelihood Ratio (LLR) mapping.
- For 8-PSK service, shall perform real-time I/Q soft decision to bit soft metric conversion.
- Shall support helical deinterleaving.
- Shall support multiple frame synchronization techniques such as freewheeling timing, frame synch header location timing and combinations of both.

- Shall support variable header sensitivity (i.e., only 95% or 90% of the frame synch bits must be observed to be correct to declare a beginning of a frame).
- Shall support resolution of data and/or channel ambiguity for QPSK and 8-PSK which may or may not require sending reacquisition or phase step commands to the receiver.
- Shall support a status interface which provides current configuration information and decoder lock status.

4.3.7.4 Turbo Product Code/ Low Density Parity Check Decoding Code Frame Synchronization Markers

a. The high rate receiver equipment shall be capable of operating in the presence of bit patterns which systematically occur inside the TPC and/or LDPC code blocks when the code frame synchronization marker pattern has a normalized cross-correlation magnitude less than or equal to 0.75 with any pattern that systematically occurs in the data before encoding. These systematic patterns may be due to data frame synchronization markers (For example, High Level Data Link Control (HDLC) frame synchronization marker) or encapsulated IP packets.

b. The decoder shall support programmable code frame synchronization markers up to a length of 42 bits.

4.3.8 Bit and Channel Ambiguity Resolution

This section specifies requirements on the receiver equipment for resolving the bit ambiguity and channel ambiguity for the different modulation and coding signal formats.

Bit ambiguity is defined as the uncertainty that the logical sense of the bit may be either true or complemented.

Channel ambiguity is defined for QPSK and SQPSK modulation formats as the uncertainty that the I-Channel or Q-Channel data may appear on the port designated for the I-Channel data, and conversely, the I-Channel or Q-Channel data may appear on the port designated for the Q-Channel data.

4.3.8.1 Bit Ambiguity Resolution

For the following signal designs, bit polarity ambiguity shall be resolved when using Non-Return to Zero-Mark (NRZ-M) or Non-Return to Zero-Space (NRZ-S):

a. Uncoded BPSK, Single Channel Configuration.
b. Coded BPSK, Single Channel Configuration.
c. Uncoded QPSK, Dual Channel Configuration.
d. Coded QPSK, Dual Channel Configuration, coding on both channels.
e. Coded QPSK, Dual Channel Configuration, coding on only one channel.
f. Rate ½ Coded QPSK, Single Channel Configuration (Alternate I/Q Symbols).

g. Uncoded SQPSK, Dual Channel Configuration.
h. Uncoded SQPSK, Single Channel Configuration.
i. Coded SQPSK, Dual Channel Configuration, coding on both channels.
j. Coded SQPSK, Dual Channel Configuration, coding on only one channel.
k. Coded SQPSK, Single Channel Configuration (Alternate I/Q Symbols).
l. Coded SQPSK, Single Channel Configuration (Alternate Data Bits).

4.3.8.2 Channel Ambiguity Resolution

Channel ambiguity shall be resolved for the following:

a. Dual Channel QPSK if at least one of the following conditions apply:
   - I/Q power ratio is 4:1.
   - One data channel is coded, the other channel is uncoded.
   - One channel symbol rate differs by more than 25% from the other channel symbol rate.
b. Dual Channel SQPSK if at least one of the following conditions apply:
   - I/Q power ratio is 4:1.
   - One data channel is coded, the other channel is uncoded.
c. Uncoded Single Channel SQPSK
d. Coded Single Channel SQPSK (Alternate Data Bits)
e. Coded Single Channel SQPSK (Alternate I/Q Symbols)
f. Coded Single Channel QPSK

4.3.9 Probability Of Error Requirements

4.3.9.1 Probability Of Error Requirements for Uncoded Signal Formats

The following probability of error (P_E) requirements apply to uncoded signal formats:

a. For the range of error probabilities specified below, the following P_E performance shall be achieved for uncoded signal formats:

   $C/N_0 = E_b/N_0 + 10 \log R_b + L(P_E , R_b)$

   Where;

   - $10^{-7} \leq P_E \leq 10^{-5}$
   - R_b is the bit rate of the data channel.
   - E_b/N_0 is the theoretical required value for P_E in an AWGN channel as defined in Table 4-7.
   - $L(P_E , R_b)$ is the allowable implementation loss (see Table 5-42 of 530-RSD-WSC) that includes:

- Customer transmit signal distortions as defined in 450-SNUG, Revision 8 for both KuSAR and KaSAR services.
- TDRS signal distortions as defined in Section 5.3.2.3.2.6e of 530-RSD-WSC.
- Ground terminal signal distortions as defined in paragraph 4.2.3.b.

b. The specified performance shall be achieved for each data channel.

c. The total C/N_0 is referenced at the SGLT Antenna Subsystem output and is defined as follows:

- QPSK & SQPSK; Dual Data Channel. C/N_0 is the combination of the I and Q Channel C/N_0s where the individual channel C/N_0s are each in accordance with the formulation in item a.

- SQPSK; Single Data Channel. The total C/N_0 is in accordance with the formulation in item a.

4.3.9.2 P_E Requirements for Rate ½ Signal Formats

The following P_E requirements apply to rate ½ coded signal formats:

a. For the range of error probabilities specified below, the following P_E performance shall be achieved for rate ½ signal formats:

$C/N_0 = E_b/N_0 + 10 \log R_b + L(P_E , R_b)$

Where;

- $10^{-7} \leq P_E \leq 10^{-5}$
- R_b is the bit rate of the data channel.
- E_b/N_0 is the theoretical required value for P_E in an AWGN channel as defined in Table 4-7.
- $L(P_E , R_b)$ is the allowable implementation loss (see Table 5-41 of 530-RSD-WSC) that includes:
  - Customer transmit signal distortions as defined in 450-SNUG, Revision 8 for both KuSAR and KaSAR services.
  - TDRS signal distortions as defined in section 5.3.2.3.2.6e of 530-RSD-WSC.
  - Ground terminal signal distortions as defined in paragraph 4.2.3.b.

b. The specified performance shall be achieved for each data channel.

c. The total C/N_0 is referenced at the SGLT Antenna Subsystem output and is defined as follows:

- QPSK & SQPSK; Dual Data Channel. C/N_0 is the combination of the I and Q Channel C/N_0s where the individual channel C/N_0s are each in accordance with the formulation in item a.

- QPSK & SQPSK; Single Data Channel. The total C/N_0 is in accordance with the formulation in item a.

4.3.9.3 P_E Requirements for SQPSK With LDPC and/or TPC

The following P_E requirements apply to SQPSK with LDPC and/or TPC signal format:

a. For the range of error probabilities specified below, the following P_E performance shall be achieved for a single channel SQPSK with LDPC and/or TPC signal format:

$$C/N_0 = E_b/N_0 + 10 \log R_b + L(P_E , R_b)$$

Where;

- 10^{-10} ***(TBR)*** $\leq P_E \leq 10^{-5}$
- R_b is the bit rate of the data channel.
- E_b/N_0 is the theoretical required value for P_E in an AWGN channel as defined in Table 4-7.
- $L(P_E , R_b)$ is the allowable implementation loss (see Table 4-8) that includes:
    - Customer transmit signal distortions as defined in Appendix B, Section B.1.
    - TDRS signal distortions as defined in Appendix B, Sections B.2-B.3.
    - Ground terminal signal distortions as defined in paragraph 4.2.3.b.

b. The specified performance shall be achieved for the single data channel.

c. The total C/N_0 is referenced at the SGLT Antenna Subsystem output.

4.3.9.4 P_E Requirements for 8-PSK With LDPC and/or TPC

The following P_E requirements apply to 8-PSK with LDPC and/or TPC signal format:

a. For the range of error probabilities specified below, the following P_E performance shall be achieved for a single channel 8-PSK with LDPC and/or TPC signal format:

$$C/N_0 = E_b/N_0 + 10 \log R_b + L(P_E , R_b)$$

Where;

- 10^{-10} ***(TBR)*** $\leq P_E \leq 10^{-5}$

Table 4-7. Theoretically Required E_b/N_o: 225-MHz Data Service

Configuration	Theoretically Required E_b/N_o (dB)			
	10^{-5} BER	10^{-7} BER	10^{-9} BER	10^{-10} BER (TBR)
Uncoded BPSK (NRZ-L) [1]	9.6	11.3	12.55	13.05
Uncoded BPSK (NRZ-M,S) [1]	9.9	11.5	12.7	13.2
BPSK rate ½ Convolutional coded (NRZ-L) [1]	4.2	5.4	6.2	6.7
BPSK rate ½ Convolutional coded (NRZ-M,S) [1]	4.4	5.55	6.35	6.85
QPSK/SQPSK Uncoded (NRZ-L) [1]	9.6	11.3	12.55	13.05
QPSK/SQPSK Uncoded (NRZ-M,S) [1]	9.9	11.5	12.7	13.2
QPSK/SQPSK rate ½ Convolutional Coded (NRZ-L) [1]	4.2	5.4	6.2	6.7
QPSK/SQPSK rate ½ Convolutional Coded (NRZ-M,S) [1]	4.4	5.55	6.35	6.85
SQPSK TPC/LDPC coded:				
TPC, (128,120)x(128,120) [2]	3.85	4.1	4.3	4.4
TPC, (256,239)x(256,239) [4]	3.75	3.95	4.15	4.25
LDPC, (8160,7136) [3]	4.35	4.6	4.9	5.05
8-PSK coded:				
TPC, (128,120)x(128,120) [2]	6.85	7.1	7.25	7.35
TPC, (256,239)x(256,239) [4]	6.75	6.95	7.1	7.2
LDPC, (8160,7136) [5]	7.3	7.45	7.6	7.7

NOTES

1. For uncoded signal formats, E_b/N_o's for NRZ-L were analytically derived using the complementary error function. For rate ½ coded signal formats, E_b/N_o's for NRZ-L were derived from theoretical curves. Then, E_b/N_o's for differentially formatted data (symbols) (that is, -M and –S) were determined by dividing the BER by two for NRZ-L and calculating the resultant E_b/N_o.
2. Theoretical values determined using simple AWGN simulations with five decoding iterations and 7-bit quantization. 10^{-10} values were extrapolated.
3. Theoretical values obtained from "Low Density Parity Check Codes: Bandwidth Efficient Channel Coding, " NASA/GSFC Code 567, Wai Fong, et al. The 10^{-7}, 10^{-9}, and 10^{-10} values were extrapolated.
4. Based on data and information provided by Efficient Channel Coding, Inc.
5. The 10^{-5} theoretical value determined using simple AWGN simulations with five decoding iterations and 7-bit quantization. The 10^{-7}, 10^{-9}, and 10^{-10} values were extrapolated.

Table 4-8. Implementation Loss: Coded SQPSK

4.3.9.3.a	Data Rate (Mbps)	Implementation Loss (dB)			
		(i) 10^{-5}	(ii) 10^{-7}	(iii) 10^{-9}	(iiii) 10^{-10} (TBR)
(1)	SQPSK TPC (128,120) x (128,120) [1]				
(1a)	150	1.6	1.7 (TBR)	1.8 (TBR)	1.9 (TBR)
(1b)	200	1.8	1.9 (TBR)	2.0 (TBR)	2.1 (TBR)
(1c)	300	2.3	2.4 (TBR)	2.5 (TBR)	2.6 (TBR)
(1d)	400	3.6	3.8 (TBR)	4.0 (TBR)	4.2 (TBR)
(1e)	410	4.0	4.2 (TBR)	4.4 (TBR)	4.6 (TBR)
(2)	SQPSK TPC (256,239) x (256,239) [2]				
(2a)	150	1.6	1.7 (TBR)	1.8 (TBR)	1.9 (TBR)
(2b)	200	1.8	1.9 (TBR)	2.0 (TBR)	2.1 (TBR)
(2c)	300	2.3	2.4 (TBR)	2.5 (TBR)	2.6 (TBR)
(2d)	400	3.6	3.8 (TBR)	4.0 (TBR)	4.2 (TBR)
(2e	410	4.0	4.2 (TBR)	4.4 (TBR)	4.6 (TBR)
(3)	SQPSK LDPC (8160,7136) [1]				
(3a)	150	1.6	1.7 (TBR)	1.8 (TBR)	1.9 (TBR)
(3b)	200	1.6	1.7 (TBR)	1.8 (TBR)	1.9 (TBR)
(3c)	300	2.5	2.6 (TBR)	2.8 (TBR)	3.0 (TBR)
(3d)	400	3.6	3.8 (TBR)	4.0 (TBR)	4.2 (TBR)
(3e)	410	4.0	4.2 (TBR)	4.4 (TBR)	4.6 (TBR)

Notes

1. 10^{-5} BER values derived from Modulation and Coding Study simulations by ITT Industries (John Wesdock, Chitra Patel). 10^{-7}, 10^{-9}, and 10^{-10} BER values are TBR because they were estimated based on E_b/N_o curves developed from 10^{-3} to 10^{-6} BER simulation results.
2. Although not directly simulated, the larger block size of the (256,239)x(256,239) TPC (as compared to the (128,120)x(128,120) TPC) should result in performance equal to or better than the (128,120)x(128,120) TPC code.

Table 4-9. Implementation Loss: Coded 8-PSK

4.3.9.4.a	Data Rate (Mbps)	Implementation Loss (dB)			
		(i) 10^{-5}	(ii) 10^{-7}	(iii) 10^{-9}	(iiii) 10^{-10} (TBR)
(1)	8-PSK TPC (128,120)x (128,120) [1]				
(1a)	150	1.5	1.6 (TBR)	1.7 (TBR)	1.8 (TBR)
(1b)	400	1.5	1.6 (TBR)	1.7 (TBR)	1.8 (TBR)
(1c)	450	2.0	2.0 (TBR)	2.1 (TBR)	2.2 (TBR)
(1d)	500	2.1	2.2 (TBR)	2.4 (TBR)	2.6 (TBR)
(1e)	550	2.6	2.6 (TBR)	2.8 (TBR)	3.0 (TBR)
(1f)	600	3.2	3.3 (TBR)	3.5 (TBR)	3.7 (TBR)
(1g)	625	4.0	4.2 (TBR)	4.4 (TBR)	4.6 (TBR)
(2)	8-PSK TPC (256,239)x (256,239) [2]				
(2a)	150	1.5	1.6 (TBR)	1.7 (TBR)	1.8 (TBR)
(2b)	400	1.5	1.6 (TBR)	1.7 (TBR)	1.8 (TBR)
(2c)	450	2.0	2.0 (TBR)	2.1 (TBR)	2.2 (TBR)
(2d)	500	2.1	2.2 (TBR)	2.4 (TBR)	2.6 (TBR)
(2e)	550	2.6	2.6 (TBR)	2.8 (TBR)	3.0 (TBR)
(2f)	600	3.2	3.3 (TBR)	3.5 (TBR)	3.7 (TBR)
(2g)	625	4.0	4.2 (TBR)	4.4 (TBR)	4.6 (TBR)
(3)	8-PSK LDPC (8160,7136) [1]				
(3a)	150	1.7	1.8 (TBR)	1.9 (TBR)	2.0 (TBR)
(3b)	400	1.7	1.8 (TBR)	1.9 (TBR)	2.0 (TBR)
(3c)	450	2.0	2.1 (TBR)	2.2 (TBR)	2.3 (TBR)
(3d)	500	2.2	2.3 (TBR)	2.4 (TBR)	2.5 (TBR)
(3e)	550	2.9	2.9 (TBR)	3.1 (TBR)	3.3 (TBR)
(3f)	600	3.7	3.9 (TBR)	4.0 (TBR)	4.2 (TBR)
(3g)	625	4.7	4.9 (TBR)	5.1 (TBR)	5.3 (TBR)

Notes

1. 10^{-5} BER values derived from slide 9 in "TDRSS K-Band Upgrade Project Modulation and Coding Study, 19 May 2004, ITT Industries, John Wesdock, Chitra Patel. 10^{-7}, 10^{-9}, and 10^{-10} BER values are TBR because they were estimated based on E_b/N_o curves developed from 10^{-3} to 10^{-6} BER simulation results.
2. Although not directly simulated, the larger block size of the (256,239)x(256,239) TPC (as compared to the (128,120)x(128,120) TPC) should result in performance equal to or better than the (128,120)x(128,120) TPC code.

- R_b is the bit rate of the data channel.
- E_b/N_0 is the theoretical required value for P_E in an AWGN channel as defined in Table 4-7.
- $L(P_E, R_b)$ is the allowable implementation loss (see Table 4-9) that includes:
  - Customer transmit signal distortions as defined in Appendix B, Section B.1.
  - TDRS signal distortions as defined in Appendix B, Sections B.2-B.3.
  - Ground terminal signal distortions as defined in paragraph 4.2.3.b.

b. The specified performance shall be achieved for the single data channel.

c. The total C/No is referenced at the SGLT Antenna Subsystem output.

4.3.10 Customer Frequency Dynamics

This paragraph does not provide requirements, just signal constraints referenced by other requirement paragraphs in this document. The high rate receiver equipment contained within the KSA HDR HWCI will be capable of supporting all requirements in Section 4.3 of this document when Customer platforms have the following dynamics:

Velocity: ≤ 12.0 km/s, resulting in Doppler as follows:

- Ku-Band: ≤ ±1.2 MHz at 15.0034 GHz (2-way Doppler).
- Ka-Band: ≤ ±1.1 MHz at 27.48 GHz (1-way Doppler).

Acceleration: ≤ 15 m/s^2, resulting in Doppler rate as follows:

- Ku-Band: ≤ ±1.5 kHz/s at 15.0034 GHz (2-way Doppler).
- Ka-Band: ≤ ±1.4 kHz/s at 27.48 GHz (1-way Doppler).

Doppler acceleration: ≤ 0.02 m/s^3, resulting in Doppler acceleration as follows:

- Ku-Band: ≤ ±2.0 Hz/s^2 at 15.0034 GHz (2-way Doppler).
- Ka-Band: ≤ ±1.8 Hz/s^2 at 27.48 GHz (1-way Doppler).
- Ku-Band during TDRS Maneuvers (Periods of 50 msec maximum, duration spaced at least 1 second apart): ≤ ±30.0 Hz/s^2.
- Ka-Band during TDRS Maneuvers (Periods of 50 msec maximum, duration spaced at least 1 second apart): ≤ ±55.0 Hz/s^2.

4.3.11 Receiver Equipment Control & Monitor

a. The receiver equipment of the KSA HDR HWCI shall be controllable via front panel controls.

b. The receiver equipment of the KSA HDR HWCI shall be controllable remotely via the CDCN.

c. The receiver equipment of the KSA HDR HWCI shall provide equipment and performance status data to the CDCN as commanded, at a minimum rate of once per second.

d. The receiver equipment shall be configurable in accordance with commands received from the front panel controls or CDCN as follows as a minimum:

    1. Operational Modes (CDCN only):
        a. Online.
        b. Standby.
        c. Maintenance-Test Mode.
    2. Center frequency and center frequency uncertainty up to ±2.4 MHz.
    3. Power ratio (I/Q) predict.
    4. Select modulation (BPSK, QPSK, SQPSK, or 8-PSK).
    5. Symbol rate (I and Q).
    6. Data Format (NRZ-L, M, S) on each channel.
    7. Viterbi decoder (On/Off):
        a. G2 Vector (norm/inverted).
        b. Number of decoders in parallel per channel (up to 8 on each channel).
    8. TPC and/or LDPC decoder:
        a. On/Off.
        b. Parameters.
    9. Differential decoder (I&Q) (On/Off).
    10. Multiplex (On/Off) – Single Channel.
    11. Status request.
    12. Data Filter.
    13. Carrier Tracking Loop Bandwidth.
    14. Bit Synchronizer Loop Bandwidth.
    15. ABBE (ON/Bypass).

e. The receiver equipment shall provide equipment status, upon request to the CDCN as follows as a minimum:

    1. Local/Remote.
    2. Operational Modes:
        a. Online.
        b. Standby.
        c. Maintenance-Test Mode.
    3. Configuration status.
    4. Equalizer selected.
    5. Data format(s) selected.
    6. Decoder configuration.

7. Symbol rates (I and Q).
8. Modulation (BPSK, QPSK, SQPSK, or 8-PSK).
9. Summary faults(s).
10. Carrier lock.
11. Lock status (I and Q):
    a. Symbol Lock.
    b. Decoder sync.
12. Bit Error Rates (I&Q).
13. ABBE converged.
14. Eb/No estimate (I&Q).
15. Selected test configuration if applicable.

f. The receiver equipment shall provide self-testing support.

g. The receiver equipment shall support maintenance commands to perform self test for the purpose of isolating any defective LRUs.
1. When commanded to fault isolate, the receiver equipment shall identify any defective LRUs.
2. Upon command, the receiver equipment shall report the identification (ID) number of the faulty LRU to the CDCN for at least 90% of LRU faults.
3. Upon command, the receiver equipment shall report the ID number of the faulty LRU to the CDCN with a maximum false detect probability of 5%.

4.4 KSAR Antenna Autotracking Requirements

This section provides the requirements to support TDRS antenna autotracking for the KSAR services provided by the TKUP modifications.

4.4.1 Support for SN Antenna Autotracking

For TPC and/or LDPC signal formats, the receiver equipment of the KSA HDR HWCI shall provide the following to the antenna autotrack receiver in order to support the antenna autotracking system:

a. Signal Presence Indicator.
b. Recovered AM Envelope.

4.4.2 Antenna Autotracking Requirements

The SGLT shall be capable of supporting TDRS SA antenna autotrack processing via ground terminal hardware as specified below:

a. For TPC and/or LDPC signal formats, the KSA HDR HWCI shall recover the SA antenna AM autotrack signal described in Appendix A.
b. For TPC and/or LDPC signal formats, the KSA HDR HWCI shall develop an indication of signal presence/absence.

4.4.3 Autotrack Acquisition Time

The following acquisition performance requirements shall apply:

a. The recovery of the AM envelope by the TKUP equipment shall occur within a time such that autotrack acquisition by the SGLT shall occur in ≤ 10 seconds with a probability > 0.99 if the C/N_o at the input to the KSA HDR HWCI is 64 dB-Hz (6 dB below the 70 dB-Hz value in Section 4.3.3) or at a level that is 6 dB (TBR) less than the C/N_o required for a BER of 10^{-5}, whichever is greater.

b. Autotrack acquisition and subsequent autotracking shall be achieved for Customer incidental AM of 5%, peak (0.6%, 10 Hz to 2 kHz; and < 3.0%, 10 Hz to 10 kHz) and in-band incidental AM added by TDRS F1-F7 and TDRS F8-F10 ≤ 1%. The 5% peak Customer incidental AM applies at frequencies > 100 Hz.

4.4.3.1 Customer Platform Signal Modulation Characteristics

All SA antenna autotrack requirements for the TKUP receiver shall be met when the Customer platform transmits a continuous wave (CW) signal or a signal with characteristics defined in:

- Table 4-5 of this document.
- 450-SNUG, Revision 8, Section 7.3 (KuSAR service) and Section 8.3 (KaSAR service).
- Table B-1 of this document for TPC and/or LDPC signal formats.

4.5 KuSAR Doppler Support for TPC and/or LDPC Signal Formats

a. The KSA HDR receiver equipment shall implement a frequency counter.

b. The frequency counter shall have the following characteristics:

    1. Accumulate a non-destructive count of the Doppler frequency based on the accumulation of the tracked carrier phase.
    2. Accumulate the frequency under worst case signal dynamics for at least 50 minutes without destructive overflow.
    3. The measurements represent the accumulation at 1-Pulse Per Second (PPS) marks.
    4. The error in the Doppler frequency measurement includes only the following:
        a. Error introduced by the ±25 ns uncertainty of the CTFS 1-PPS signal
        b. 0.2 radians/sec, rms due to phase noise of incoming signal.
        c. Error introduced by the 4.0×10^{-12} CTFS Frequency accuracy.

c. The accumulated frequency shall be reported once per second to the SA ADPEs via the KSA Control HWCI.

NOTE

For all non-TPC and/or LDPC signal formats, the KSA HDR HWCI will continue to support Doppler measurements by only providing the 370 MHz IF modulated signal to the IR which is the current SN method for supporting Doppler measurements.

4.6 WSC DIS and GRGT LI High Rate Switching Requirements

This section provides the data distribution requirements for the STGT and WSGT DIS High Rate Switches, and the GRGT High Rate LI Switch.

4.6.1 WSC DIS High Rate Switching Requirements

Currently, the STGT DIS and WSGT DIS both have a HRBS HWCI that contains a HRDS. The HRDS enables customer return data from the KSA HDR HWCI receivers to be connected to the High Density Digital Recorders (HDDRs), the Common Carrier Interface (CCI), and the HDR multiplexers/demultiplexers. Figure 4-1 illustrates the STGT and WSGT HRDS current interfaces to WSC equipment. The HRDS also routes high rate customer return data to multiple, customer-dedicated point-of-presences, designated as LI.

The new switching unit will support data rates up to 625 Mbps. Also, the new switching unit will have interfaces to the Low Rate Black Switch (LRBS) HWCI.

4.6.1.1 Legacy Interface, HRDS Functional Replacement

Each of the WSC DIS HRDS Units, in order to replace all interfaces and functions supported by the existing HRDS shall at a minimum:

a. Provide legacy interface capacity adequate to support all WSC equipment interfaces currently supported by each of the existing HRDS, excluding the interfaces to the KSAR USS Return Equipment Groups.
b. Provide legacy interface capacity adequate to support all HRDS-to-Low Rate Digital Switch interconnections currently supported by each of the existing HRDS.
c. Provide legacy interface capacity adequate to support all STGT-to-WSGT HRDS switch interconnections currently supported by each of the existing HRDS units.
d. Provide legacy interface capacity adequate to support all existing STGT and WSGT customer local interfaces.
e. Provide legacy interface capacity adequate to provide the same number of spare legacy interface switch ports as the existing HRDS.
f. Support information rates from 2 Mbps to 300 Mbps for all legacy interface functions.
g. Provide interface compatibility with all equipment or equipment groups and Local Interfaces currently supported by the HRDS.

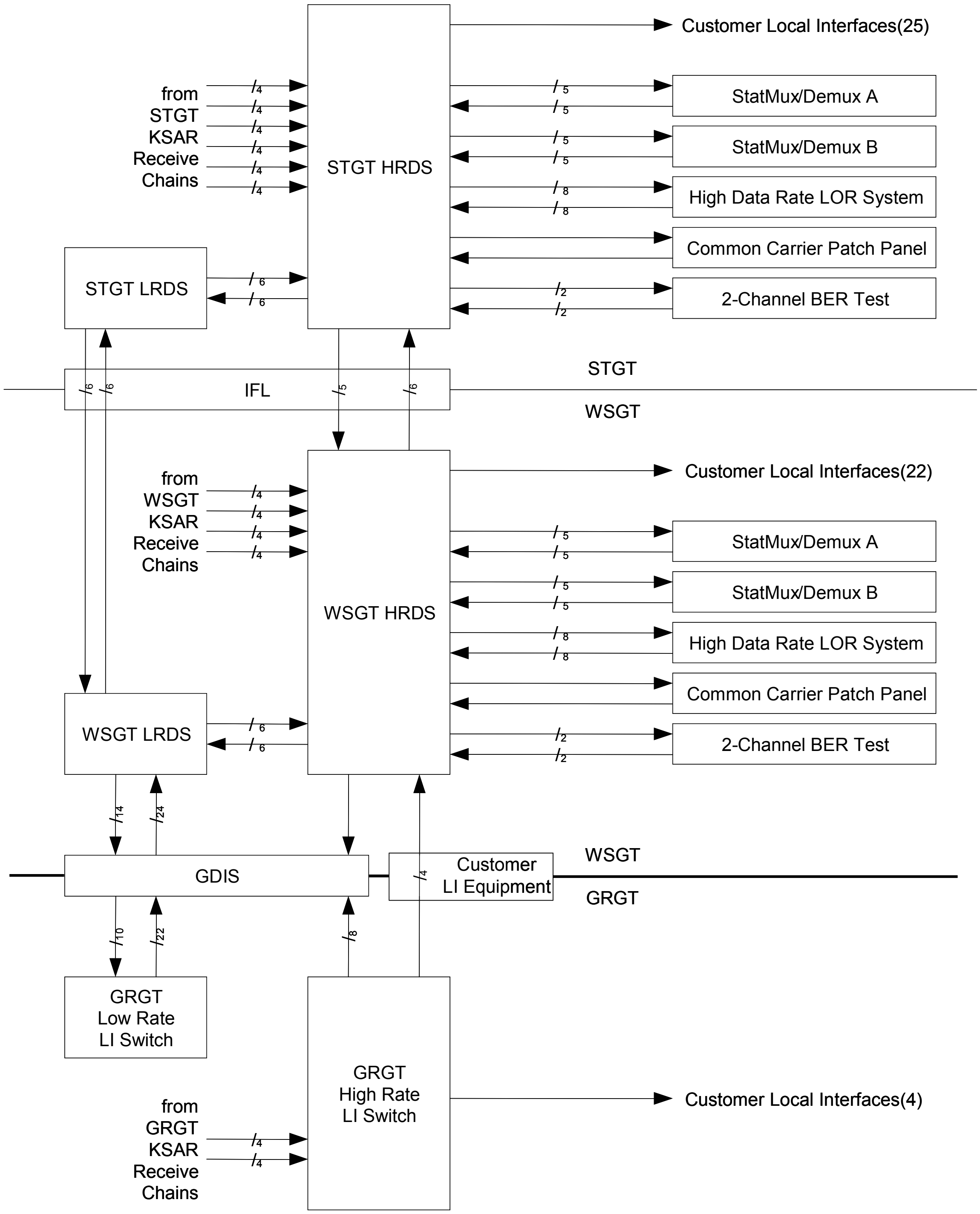


Figure 4-1. HRDS Interfaces to WSC Equipment

NOTE

Interface compatibility may be achieved, on an interface-by-interface basis, by providing an electrically and functionally equivalent interface to the synchronous, differential-ECL interface currently provided by the HRDS, as defined in Appendix D, or by providing an alternative interface definition that would require equipment interface modifications.

4.6.1.2 Evolutionary Interface, TKUP Expanded Data Rate Switching

Each of the WSC/DIS HRDS Units, in order to support the distribution of recovered, baseband customer data that exceeds the current 300 Mbps maximum data rate, and to support the receipt and distribution of customer forward data, shall at a minimum:

a. Provide ≥ 24 evolutionary interfaces to receive recovered customer baseband data from the KSAR USS receive chains.
b. Support information rates from 2 Mbps to 625 Mbps for all evolutionary interfaces to the KSAR USS receive chains.
c. Provide ≥ 12 evolutionary customer data interfaces (local interfaces).
d. Be scalable to ≥ 64 evolutionary customer data interfaces.
e. Support information rates of 2 Mbps to 625 Mbps in the direction of the HRDS to the evolutionary customer data interfaces.
f. Support information rates of 1000 bps to 50 Mbps in the direction of the customer to the HRDS evolutionary customer data interfaces.

4.6.1.3 Switch Control and Status

The switching unit shall:

a. Provide a remote status and control interface to be used for reconfiguration, to perform diagnostics and maintenance functions, and to monitor the health and performance of the switch.
b. Provide a local status and control interface to be used for reconfiguration, to perform diagnostics and maintenance functions, and to monitor the health and performance of the switch.
c. Provide a built-in self-test function.

4.6.1.4 Signal Switching

The switching unit shall be capable of switching its signal inputs to its output ports using the following:

a. All signal routing shall be performed under commands from the following:
    1. Remote interface.
    2. Local control.
b. The switch shall support multi-cast delivery of data received at any interface input to one or any number of interface outputs.

c. Where applicable, all signals constituting a selected signal input shall be switched to the selected output using one switching command. In the case of interfaces conforming to the existing switch interface, this would include data, clock, and their respective complements. (Complement refers to differential data and clock signaling. For example, Data- is complement of Data+ and Clock- is complement of Clock+).

d. Signal switching shall not cause any input to output data/signal inversion.

e. Configuration or reconfiguration of a path or group of paths shall not interfere with normal operation of active paths not being configured.

f. Adding switch connections to an existing circuit without breaking the existing connection shall be supported.

4.6.1.5 Redundancy

The switch unit shall provide redundancy such that any component of the switch function can be taken off line without compromising system performance or capacity.

4.6.1.6 Bit Error Rate

a. The switching unit shall have an overall end-to-end BER less than or equal to 1×10^{-12} for any single input to output circuit.

b. The BER shall be met in all operating modes, including, but not limited to:

   1. Worst case crosstalk.
   2. Broadcast mode.
   3. During reconfiguration of channels.

4.6.1.7 Reconfiguration Time

Any path of the switching unit with a single output or multiple outputs shall be reconfigurable in less than or equal to 350 ms.

4.6.2 GRGT LI High Rate Switching Requirements

Currently, the GRGT has a High Rate LI Switch. The LI switch enables customer return data from the KSA HDR HWCI receivers to be connected to the GRGT LI and other GRGT equipment.

The new switching unit will support data rates up to 625 Mbps.

4.6.2.1 GRGT High Rate LI Switching Requirements

The GRGT HRDS Unit, in order to replace all interfaces and functions supported by the current GRGT High Rate LI, shall at a minimum:

a. Provide legacy interface capacity adequate to support all GRGT equipment interfaces currently supported by each of the existing HRDS, excluding the interfaces to the KSAR USS Return Equipment Groups.

b. Provide legacy interface capacity adequate to support all existing GRGT customer local interfaces.

c. Provide legacy interface capacity adequate to provide the same number of spare legacy interface switch ports as the existing GRGT High Rate LI Switch.
d. Support information rates from 2 Mbps to 300 Mbps for all legacy interface functions.
e. Provide interface compatibility with all equipment or equipment groups and Local Interfaces currently supported by the GRGT High Rate LI Switch.

NOTE

> Interface compatibility may be achieved, on an interface-by-interface basis, by providing an electrically and functionally equivalent interface to the synchronous, differential-ECL interface currently provided by the HRDS, as defined in Appendix D, or by providing an alternative interface definition that would require equipment interface modifications.

4.6.2.2 Evolutionary Interface, TKUP Expanded Data Rate Switching

The GRGT HRDS Unit, in order to support the distribution of recovered, baseband customer data that exceeds the current 300 Mbps maximum data rate, and to support the receipt and distribution of customer forward data, shall at a minimum:

a. Provide ≥ 4 evolutionary interfaces to receive recovered customer baseband data from the KSAR USS receive chains.
b. Support information rates from 2 Mbps to 625 Mbps for all evolutionary interfaces to the KSAR USS receive chains.
c. Provide ≥ 12 evolutionary customer data interfaces (local interfaces).
d. Be scalable to ≥ 64 evolutionary customer data interfaces.
e. Support information rates of 2 Mbps to 625 Mbps in the direction of the HRDS to the evolutionary customer data interfaces.
f. Support information rates of 1000 bps to 50 Mbps in the direction of the customer to the HRDS evolutionary customer data interfaces.

4.6.2.3 Switch Control and Status

The switching unit shall:

a. Provide a remote status and control interface to be used for reconfiguration, to perform diagnostics and maintenance functions, and to monitor the health and performance of the switch.
b. Provide a local status and control interface to be used for reconfiguration, to perform diagnostics and maintenance functions, and to monitor the health and performance of the switch.
c. Provide a built-in self-test function.

4.6.2.4 Signal Switching

The switching unit shall be capable of switching its signal inputs to its output ports using the following:

a. All signal routing shall be performed under commands from the following:
   1. Remote interface.
   2. Local control.
b. The switch shall support multi-cast delivery of data received at any interface input to one or any number of interface outputs.
c. Where applicable, all signals constituting a selected signal input shall be switched to the selected output using one switching command. In the case of interfaces conforming to the existing switch interface, this would include data, clock, and their respective complements. (Complement refers to differential data and clock signaling. For example, Data- is complement of Data+ and Clock- is complement of Clock+.)
d. Signal switching shall not cause any input to output data/signal inversion.
e. Configuration or reconfiguration of a path or group of paths shall not interfere with normal operation of active paths not being configured.
f. Adding switch connections to an existing circuit without breaking the existing connection shall be supported.

4.6.2.5 Redundancy

The switch unit shall provide redundancy such that any component of the switch function can be taken off line without compromising system performance or capacity.

4.6.2.6 Bit Error Rate

a. The switching unit shall have an overall end-to-end BER less than or equal to 1×10^{-12} for any single input to output circuit.
b. The BER shall be met in all operating modes, including, but not limited to:
   1. Worst case crosstalk.
   2. Broadcast mode.
   3. During reconfiguration of channels.

4.6.2.7 Reconfiguration Time

Any path of the switching unit with a single output or multiple outputs shall be reconfigurable in less than or equal to 350 ms.

4.7 SN Service Management and Operations Requirements

a. The existing SN systems, excluding the UPS and SWSI, shall be modified to support service management (e.g., scheduling, status and control) of the new services.
b. The message formats specified in the 452-ICD-SN/CSM, *Interface Control Document between the Space Network and Customers for Service Management*, shall be used to the extent possible to accommodate the service management of the new services.

c. The SNAS shall be modified to support the new services.

d. The SN operator interface for the new services shall support the existing operations concept for service management.

e. The SN operator interface for the new TKUP equipment shall support the existing operations concept for the following:

   1. Configuration,
   2. Control, and
   3. Status.

4.8 KSA HDR HWCI Interface Requirements

This section specifies the interface requirements for the KSA HDR HWCI equipment. The KSA HDR HWCI equipment will interface with equipment in other HWCIs within the USS such as the IRs contained within the KSA Low Data Rate HWCI and FM Demodulators and Autotrack Receivers contained within the KSA Control HWCI. The KSA HDR HWCI equipment will also interface with the CTFS subsystem and DIS.

4.8.1 KSA Control HWCI Interfaces

4.8.1.1 370 MHz Modulated IF Signal

a. The KSA HDR HWCI shall provide the autotrack receiver a 370 MHz modulated IF signal with the following characteristics:

   1. Nominal Center Frequency: 370 MHz
   2. Level (Signal and Noise): -10 dBm ± 3 dB
   3. Nominal Impedance: 50 ohms
   4. VSWR: 1.3:1 maximum over ± 80 MHz
   5. Bandwidth: ≤ 260 MHz

b. The KSA HDR HWCI shall provide the FM demodulator a 370 MHz modulated IF signal with the following characteristics:

   1. Nominal Center Frequency: 370 MHz
   2. Level (Signal and Noise) -10 dBm ± 3 dB
   3. Nominal Impedance: 50 ohms
   4. VSWR: 1.3:1 maximum over ± 80 MHz
   5. Bandwidth: ≤ 260 MHz

4.8.1.2 Signal Presence Indicator

The KSA HDR HWCI shall provide the autotrack receiver a signal presence indicator signal with the following characteristics:

a. Interface: RS-422.

b. Logical 1: Indicates that the receiver equipment detects a signal.

c. Logical 0: Indicates that the receiver equipment detects no signal.

4.8.1.3 Recovered Amplitude Modulation Envelope

For TPC and/or LDPC signal formats, the KSA HDR HWCI shall provide the autotrack receiver a recovered AM envelope signal as follows:

a. Signal Type: Differential analog voltage

b. Level (Signal+Noise): 0 to 13 VAC, peak-to-peak

c. Nominal Impedance: 249 ohms ± 1 percent

d. 3 dB Bandwidth: 4.0 kHz ± 0.4 kHz (Rolloff equivalent to 3-pole or better)

e. AC Coupling:

   1. The detected envelope shall be AC coupled to remove the DC component.
   2. The 3 dB point of the AC coupling response shall be 50 Hz, maximum.

f. Linearity: The AC component of the recovered AM envelope signal shall be a linear function of the input signal modulation index for index values in the range of 0.1% to 13%.

g. Output Level Scaling: The output level of the recovered autotrack envelope signal shall be linearly proportional to the modulation index of the input signal, with a proportionality constant of 100 mV, differential, per 0.1% modulation index.

h. Clipping: The recovery time of the clipping circuits shall be negligibly small compared to the period of an autotrack PN code chip that is defined in Appendix A.

NOTE

Clipping of noise peaks is permitted at levels greater than three standard deviations of the noise, or ± 12 volts differential, whichever is less.

4.8.2 KSA Low Rate Equipment HWCI Interface

The KSA HDR HWCI shall provide the integrated receiver a 370 MHz modulated IF signal with the following characteristics:

a. Nominal Center Frequency: 370 MHz

b. Level (Signal and Noise): -10 dBm ± 3 dB

c. Nominal Impedance: 50 ohms

d. VSWR: 1.3:1 maximum over ± 80 MHz

e. Antenna Autotrack AM Modulation: No AM distortions added by the KSA HDR HWCI.

f. Bandwidth: ≤ 260 MHz

4.8.3 Common Time and Frequency System Input

a. The KSA HDR HWCI equipment shall accept a 10 MHz reference signal from the CTFS with the following characteristics:

1.	Center Frequency:	10 MHz
2.	Single Side Band (SSB) phase noise in 1 Hz BW:	-80 dBc maximum at 10^{-1} Hz to 10^{0} Hz offset -105 dBc maximum at 10^{0} Hz to 10^{1} Hz offset -120 dBc maximum at 10^{1} Hz to 10^{2} Hz offset -125 dBc maximum at 10^{2} Hz to 10^{3} Hz offset -140 dBc maximum at 10^{3} Hz to 10^{4} Hz offset -155 dBc maximum at 10^{4} Hz to 10^{5} Hz offset
3.	Signal Type:	Single-ended, sinusoidal
4.	Nominal Impedance:	50 ohms
5.	Short term frequency stability:	$\pm 5.0 \times 10^{-12}$ maximum for 1 sec averaging $\pm 2.7 \times 10^{-12}$ maximum for 10 sec averaging $\pm 8.5 \times 10^{-13}$ maximum for 100 sec averaging
6.	Harmonic Distortion:	Less than -50 dBc
7.	Frequency accuracy:	$\pm$ 4.0 x 10^{-12} maximum
8.	Signal Level:	+12 dBm ± 2 dB into 50 ohms
9.	Connector:	TNC female
10.	Non-Harmonically Related Spurious:	Less than -80 dBc

b. In order to support the receiver equipment frequency counter that is described in section 4.5, the KSA HDR HWCI equipment shall accept a 1 PPS signal from the CTFS with the following characteristics:

1.	Nominal Frequency:	1 Hz
2.	Signal Type:	Single ended, rectangular pulse
3.	Nominal Impedance:	50 ohms (presented as load by receiver)
4.	Signal Level:	TTL levels
5.	Pulse Width:	100 microseconds
6.	Rise and Fall Times:	10 nanoseconds, max
7.	Pulse-to-Pulse Jitter:	2 nanoseconds, Max
8.	Accuracy:	< ± 25 nanoseconds referenced to the CTFS master epoch
9.	Sense of signal:	Time epoch corresponds to the leading edge of the pulse

4.8.4 Front Panel Interface

The KSA HDR HWCI equipment shall provide the following front panel interfaces for the 370 MHz modulated IF signal:

a. Nominal Center Frequency: 370 MHz
b. Level (Signal and Noise): -10 dBm ± 3 dB
c. Nominal Impedance: 50 ohms
d. VSWR: 1.3:1 maximum over ± 80 MHz
e. Connector: SMA Female

4.8.5 Data Interface System Interface

The KSA HDR HWCI equipment shall provide the DIS, via the switching of the KSA Control HWCI, the recovered baseband data.

4.8.6 Antenna Subsystem Radio Frequency Interface

The KSA HDR HWCI equipment shall accept RF inputs from the Antenna Subsystem.

4.8.7 Performance Measuring and Monitoring System Equipment Interfaces

The KSA HDR HWCI equipment shall interface with non-KSA HDR HWCI PMMS equipment.

4.8.8 IF Output Interface

This section specifies requirements for USS KSAR IF output ports:

a. The KSA HDR HWCI shall provide one extra 370 MHz IF output port per downconverter.
b. The signal characteristics at each 370 MHz IF output port shall be as specified in Table 4-2.
c. The total signal distortions at each 370 MHz IF output port caused by the ground terminal infrastructure from the Antenna to the 370 MHz IF output port shall be as specified in Table 4-3. (All signal distortions caused by the Customer spacecraft and TDRS are listed in Appendix B for reference.).

4.9 Performance Measuring and Monitoring System Requirements

This section provides the requirements for loop testing and signal monitoring of the 225 MHz channel return high rate data services. The PMMS equipment of the KSA HDR HWCI will generate test signals necessary to verify downconverter and receiver equipment performance, long loop performance, and end-to-end performance as shown in Figure 4-2 and Figure 4-3.

4.9.1 Performance Measuring and Monitoring System Equipment Functions

4.9.1.1 General

a. The PMMS equipment shall modulate signals using the formats defined in Table 4-5.

b. The PMMS equipment shall generate low data rate signals and KSHR signals with the input signals as specified in section 4.9.2.

c. The PMMS equipment shall be capable of providing a simulated return signal with AM modulation to support testing of the antenna autotracking equipment.

d. For short loop testing, the PMMS equipment contained within the KSA HDR HWCI shall supply return link IF signals into the normal high rate KSAR 225 MHz equipment chains at a point after the downconverter.

e. For medium loop testing, the PMMS equipment contained within the KSA HDR HWCI shall supply return link IF signals to the input of the PTE test upconverters.

f. The PMMS equipment shall supply return link IF signals with the following characteristics to the input of the long loop test upconverter, contained within the Antenna Subsystem:

   1. Nominal Center Frequency: 370 MHz
   2. Level (Signal + Noise): 0 dBm ± 3 dB
   3. Nominal Impedance: 50 ohms
   4. VSWR: 1.3:1 maximum over ±80 MHz

g. The PMMS equipment shall supply return link IF signals with the following characteristics to the EET System Transmitter:

   1. Nominal Center Frequency: 370 MHz
   2. Level (Signal + Noise): 0 dBm ± 3 dB
   3. Nominal Impedance: 50 ohms
   4. VSWR: 1.3:1 maximum over ±80 MHz

h. The BERTS shall be capable of performing BER measurements.

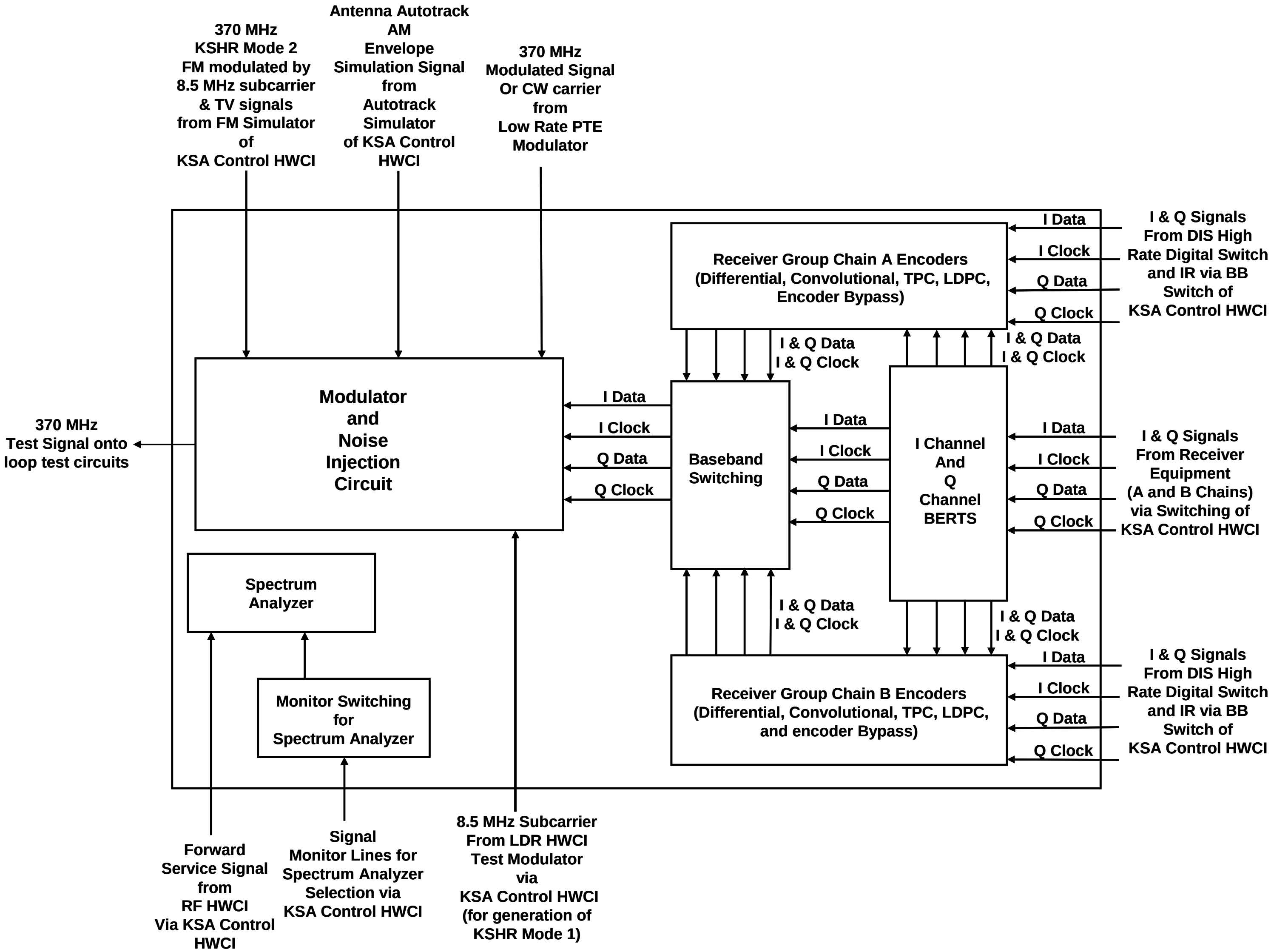


Figure 4-2. KSA HDR HWCI PMMS Equipment Functional Block Diagram

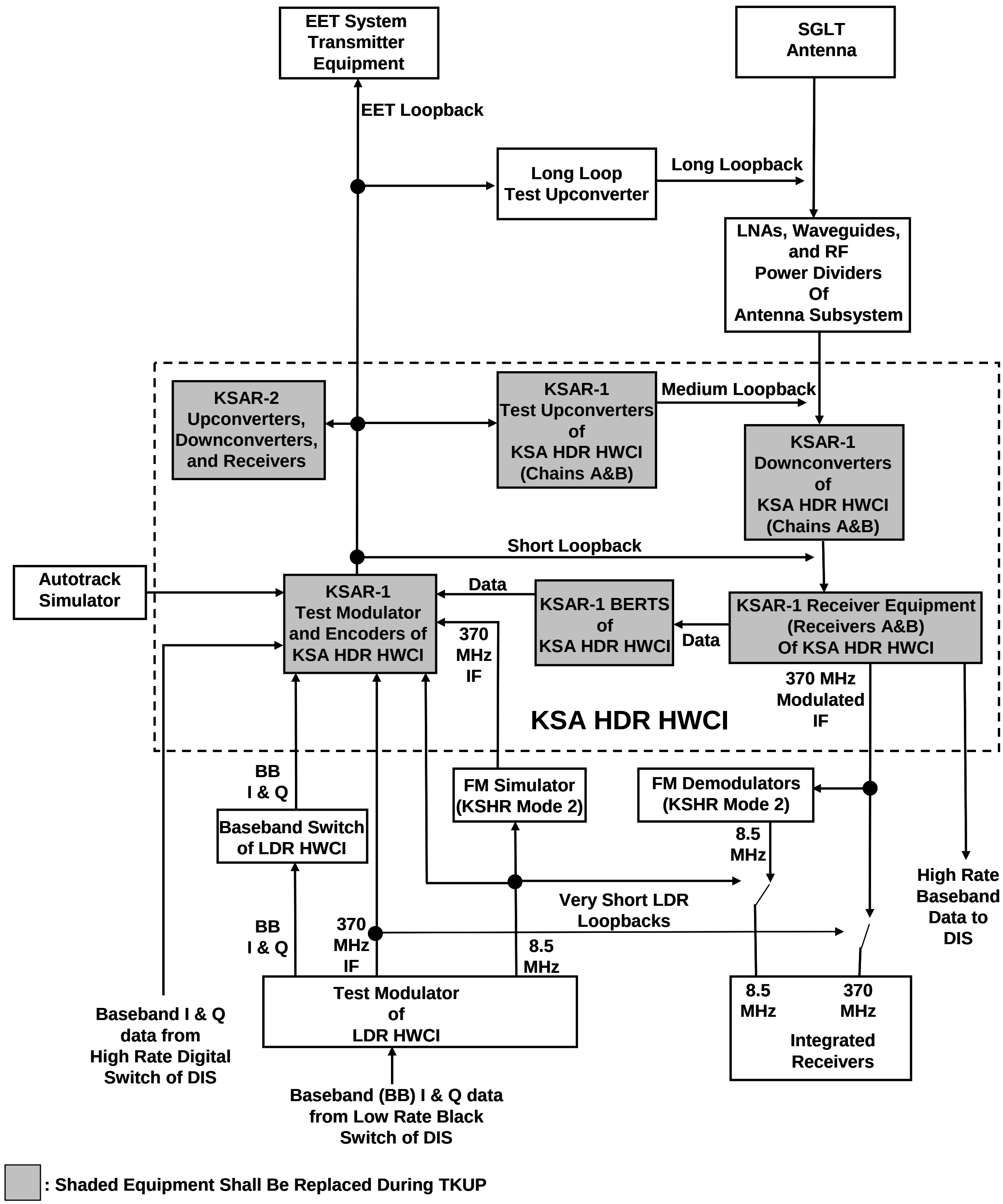


Figure 4-3. Functional Block Diagram of KSAR-1 Loop Test Configurations

4.9.1.2 Shuttle Mode 1

a. The PMMS modulation equipment shall accept the Unbalanced QPSK (UQPSK) modulated 8.5 MHz subcarrier portion of a KSHR Mode 1 signal from the Low Data Rate Equipment test modulator via the HDR Control HWCI.

b. The PMMS modulation equipment shall generate a QDSB signal by placing the 8.5 MHz subcarrier on the Q-Channel and generating data for the I-channel with characteristics as follows:

   1. 2 Mbps - 50 Mbps.
   2. NRZ-L, M, or S data format.
   3. Rate ½ convolutional encoding.

4.9.1.3 Noise Injection

a. The PMMS modulation equipment shall inject noise in the test signal.

b. The modulator C/N_o characteristics shall be as follows:

   1. Range: 60 to 105 dB-Hz.
   2. Accuracy: ±0.5 dB.
   3. Resolution: 1 dB.
   4. ON/OFF selection for Noise.

c. C/N_o shall be configurable via a remote control.

d. C/N_o shall be configurable via a front panel local control.

4.9.1.4 Power Ratio

The PMMS modulation equipment shall be capable of providing a signal with an I/Q power ratio of:

a. 1:1 with an accuracy of ± 0.4 dB, or

b. 4:1 with an accuracy of ± 0.4 dB.

4.9.2 External Inputs to Performance Measuring and Monitoring System Equipment

4.9.2.1 370 MHz Modulated IF Signal (Low Data Rate Tests)

a. The PMMS equipment shall accept a signal from the Low Data Rate Equipment HWCI (test modulator) via the KSA Control HWCI with the following characteristics:

   1. Nominal Center Frequency: 370 MHz
   2. Level (Signal + Noise): -10 dBm ± 4 dB
   3. Nominal Impedance: 50 ohms
   4. VSWR: 1.3:1 maximum over ±10 MHz
   5. 3 dB Bandwidth: 30 MHz

b. The PMMS equipment shall forward the low data rate modulated signal to the following:

   1. Short Loop.
   2. Medium Loop.
   3. Long Loop.
   4. EET Loop.

4.9.2.2 370 MHz Continuous Wave Carrier (Testing with Doppler)

a. The PMMS equipment shall accept a CW signal with Doppler adjustment from the Low Data Rate Equipment HWCI (test modulator) via the KSA Control HWCI with the following characteristics:

   1. Nominal Center Frequency: 370 MHz
   2. Level (Signal + Noise): -10 dBm ± 4 dB
   3. Nominal Impedance: 50 ohms
   4. VSWR: 1.3:1 maximum over ±10 MHz

b. The PMMS equipment shall provide the capability to use either of two frequency sources for simulated return signal generation:

   1. internal Local Oscillator (LO); or
   2. Doppler adjusted CW signal received from the LDR Equipment HWCI.

c. The frequency source for test signal generation shall be controllable via:

   1. the remote control and status interface; and
   2. local control (front panel interface)

4.9.2.3 8.5 MHz Subcarrier (For K-Band Shuttle Return Mode 1 Simulation)

a. The PMMS equipment of the KSA HDR HWCI shall accept a signal from the Low Data Rate HWCI (test modulator) via the KSA Control HWCI with the following characteristics:

   1. Nominal Center Frequency: 8.5 MHz
   2. Subcarrier Type: Square Wave (Binary PSK)
   3. Level (Signal + Noise): -10 dBm ± 4 dB
   4. Nominal Impedance: 50 ohms
   5. VSWR: 1.3:1 maximum over ± 6 MHz

b. The High Data Rate Test Modulator of the KSA HDR HWCI shall use the subcarrier along with a baseband data stream up to 50 Mbps to generate the KSHR Mode 1 simulation signal.

4.9.2.4 370 MHz K-Band Shuttle Return Mode 2

a. The PMMS equipment of the KSA HDR HWCI shall accept a signal from the KSA Control HWCI (FM Simulator) with the following characteristics:

   1. Nominal Center Frequency: 370 MHz

2. Modulation: FM
3. 3 dB Bandwidth: 50 MHz
4. Level (Signal + Noise): -10 dBm ± 4 dB
5. Nominal Impedance: 50 ohms
6. VSWR: 1.3:1 maximum over ± 18 MHz

b. The PMMS equipment shall forward the KSHR Mode 2 signal to the following:
   1. Short Loop.
   2. Medium Loop.
   3. Long Loop.
   4. EET Loop.

4.9.2.5 Antenna Autotrack Amplitude Modulation Envelope Simulation Signal

a. The PMMS equipment shall accept a signal from the KSA Control HWCI (Autotrack Simulator) with the following characteristics:
   1. Interface: Differential analog voltage transmitted over a shielded twisted pair.
   2. Level: 0 to 13 Volts Alternating Current (VAC), peak-to-peak, as measured by a differential oscilloscope across the twisted pair.
   3. Nominal Impedance: 249 ohms ± 1%

b. The KSA HDR HWCI (test modulator) shall use the simulated AM envelope signal to AM modulate the test signal.

c. The AM modulation shall be linearly proportional to the input level, with a proportionality constant of 1 percent modulation per 1 Volt.

d. The amplitude modulation shall be applied prior to the addition of noise.

e. The test modulator shall have an ON/OFF switch for the simulated AM envelope signal.

4.9.2.6 Baseband Data and Clock

The PMMS modulation/encoding equipment contained within the KSA HDR HWCI shall accept baseband data and clock from one of the following via the KSA Control HWCI:

a. BERTS transmitter.

b. High rate portion of DIS.

c. Test modulator of LDR HWCI via the low rate baseband switch of the LDR HWCI (clock and data, RS422).

4.9.3 Medium Loop Test Upconverter Requirements

a. The KSAR-1 PTE test upconverter contained within the KSA HDR HWCI shall translate 370 MHz to 13528.4 MHz

b. The KSAR-2 PTE test upconverter contained within the KSA HDR HWCI shall translate 370 MHz to 13928.4 MHz.

c. The PTE test upconverter LO frequency shall be synthesized from the CTFS 10 MHz reference.

d. The PTE upconverter shall supply the upconverted simulated KSAR return signals to the input of each downconverter.

e. PTE test upconverter shall have characteristics as follows:

1.	Local Oscillators:	Derived from CTFS 10 MHz reference and independent of LOs of downconverters
2.	Frequency Translation Factor from 370 MHz IF:	13158.4 MHz (KSA1) and 13558.4 MHz (KSA2)
3.	Bandwidth, 3dB:	300 MHz, minimum
4.	Gain Flatness:	0.6 dB peak-to-peak over ±80 MHz
5.	Gain Slope:	±0.1 dB/MHz over ±80 MHz
6.	Phase Nonlinearity:	6 degrees peak-to-peak over ±80 MHz
7.	Spurious:	-35 dBc, maximum including AM and FM from 13.3 to 14.1 GHz. Otherwise, -45 dBc, maximum for individual spur.
8.	Phase Noise (includes CTFS):	

1 Hz – 10 Hz	≤ 2.0 degrees rms
10 Hz – 100 Hz	≤ 2.0 degrees rms
100 Hz – 1 kHz	≤ 3.8 degrees rms
1 kHz – 150 MHz	≤ 1.4 degrees rms

4.9.4 TKUP Signal Distribution To Spectrum Analyzer Subsystem

The TKUP equipment shall distribute the following signals and quantity, as indicated by (#), to the spectrum analyzer subsystem:

a. Test Modulator output (1).

b. 370 MHz downconverter outputs (4).

c. I-channel and Q-channel baseband outputs from receivers (4).

4.9.5 Control & Monitor of PMMS Equipment

a. The PMMS equipment of the KSA HDR HWCI shall be controllable via front panel controls.

b. The PMMS equipment of the KSA HDR HWCI shall be controllable remotely via the CDCN.

c. The PMMS equipment of the KSA HDR HWCI shall provide equipment and performance status data to the CDCN as commanded, at a minimum rate of once per second.

d. The PMMS equipment of the KSA HDR HWCI shall be configurable in accordance with commands received from front panel controls or CDCN as follows as a minimum:

1. Operational Modes (CDCN only):
    a. Online.
    b. Standby.
    c. Maintenance-Test Mode.
2. Access to baseband and analog inputs, output IF, and selected voltage levels.
3. Modulation/data rate/coding parameter selection.
4. Local/Remote selection.

e. The PMMS equipment shall provide equipment configuration status, upon request to the CDCN.
    1. Operational Mode status.
    2. Modulation/data rate/coding status.
    3. Local/remote status.

f. The PMMS equipment shall provide self-testing support.

g. The PMMS equipment shall support maintenance commands to perform self test for the purpose of isolating any defective LRUs.
    1. When commanded to fault isolate, the PMMS equipment shall identify any defective LRUs.
    2. Upon command, the PMMS equipment shall report the identification (ID) number of the faulty LRU to the CDCN for at least 90% of LRU faults.
    3. Upon command, the PMMS equipment shall report the ID number of the faulty LRU to the CDCN with a maximum false detect probability of 5%.

4.10 TKUP System Performance Requirements

4.10.1 KSA Service Dual Data Source I/Q-Channel Skew

The time skew between I-channel and Q-channel output data for KSAR dual data source services, for which I-channel and Q-channel data rates and channel processing are identical, shall be no greater than two bit periods at the legacy (i.e., ECL) high rate switch output.

4.10.2 Maximum KSAR Data Service Path Delay

For non-TPC and/or LDPC signal formats, the signal processing path time delay (i.e., latency) between the time that the leading or trailing edge of any modulated RF signal data symbol is received at the SGL antenna feed and the time that the leading or trailing edge of the corresponding recovered baseband data and clock bits are delivered to the legacy (i.e., ECL) high rate switch output shall not exceed 28 milliseconds.

4.10.3 Maximum KSAR Data Service Path Delay Variation

For non-TPC and/or LDPC signal formats, from the time the receive equipment has achieved data detection until the end of the service or signal synchronization is lost, the signal processing path time delay (i.e., latency) between the time that the leading or trailing edge of any modulated RF signal data symbol is received at the SGL antenna feed and the time that the leading or trailing edge of the corresponding recovered baseband data and clock bits are delivered to the legacy (i.e., ECL) high rate switch output shall not vary by more than ±48 nanoseconds.

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SECTION 5. MAINTENANCE SUPPORT CAPABILITIES

5.1 Hardware Maintenance

5.1.1 Overview

The purpose of the hardware maintenance functions specified herein is to provide the capability to maintain and repair TKUP hardware to support achievement of the required operational availability of all TKUP systems for their entire lifecycle.

5.1.2 Definitions

5.1.2.1 Line Replaceable Unit

A rack-mounted equipment drawer or chassis, a printed circuit card and other plug-in component, or any other assembly is considered a LRU if it can be removed, possibly requiring the unplugging of power and signal connectors, without physically disturbing other LRUs or other components of the system of which it is a part. A LRU itself may be in part or in whole made up of constituent LRUs.

5.1.2.2 First Level Maintenance

First level maintenance includes the isolation of the cause of hardware defects in any operational system to one specific, or several specific, suspect LRU or LRUs and the replacement of the identified LRU or LRUs, restoring the system to a serviceable condition in which it meets all functional and performance requirements.

5.1.2.3 Second Level Maintenance

Second level maintenance includes the action required to restore a malfunctioning LRU to serviceable condition, and the verification that the repaired LRU meets all functional and performance requirements. Second Level maintenance also includes the restoration of a malfunctioning equipment or system when the fault isolation capabilities of first level maintenance are incapable of localizing a failure to a line replaceable item within the equipment or system.

5.1.3 First Level Maintenance Test Group

A first level Maintenance Test Group (MTG) function shall be provided that consists of all general and special purpose test equipment and other items that are not included as part of the operational systems that are required to perform first level maintenance of the TKUP hardware.

5.1.3.1 Preventive Maintenance

The MTG function shall prescribe all preventive maintenance activities that are required to support the achievement of the required operational availability. These activities include any periodic equipment tests and characterization, and any periodic alignment procedures that are required to maintain the required operational availability.

5.1.3.2 Spare LRU Provisioning

The MTG function shall prescribe the level of spare LRUs that are required to support the achievement of the required operational availability.

5.1.4 Hardware Maintenance Depot

A Hardware Maintenance Depot (HMD) function shall be provided that consists of all general and special purpose test equipment and other resources that are not involved in operational systems support or in the MTG and are required to perform second level maintenance of the TKUP hardware. As a goal to the extent feasible and cost effective, the HMD function should be implemented by augmenting the capabilities of the existing HMD at the WSC.

5.1.4.1 Second Level Maintenance Requirements

Second level maintenance shall support the achievement of the required operational availability of all ground systems over the lifecycle of the systems including achievement of first level maintenance requirements.

5.2 Software Maintenance

5.2.1 Overview

The purpose of the software maintenance functions specified herein is to provide the ability to maintain, modify, and enhance the software of all systems that make up the TKUP; this includes all non-operational systems as well as operational systems, such as software systems that are part of special test equipment that is part of the MTG or HMD.

For the purpose of TKUP requirements, no distinction is made between software and firmware unless that distinction is explicitly stated. All discussion and requirements referencing software herein apply to firmware also, except where otherwise stated.

As a goal to the extent feasible and cost effective, the software maintenance function should be implemented by augmenting the capabilities of the existing Software Maintenance and Test Facility (SMTF) at the WSC.

5.2.2 General Requirements

A software maintenance function shall be provided that:

a. Includes the resources required to affect desired changes to operational and non-operational software.
b. Includes the testing resources required to ensure that new and modified software meets all existing functional and performance specifications and, in the case of enhancements, meets all newly defined functional and performance requirements.
c. Includes the verification resources required to ensure that the delivery of software modifications to operational systems will not compromise the required operational availability of those systems.

d. Includes the capabilities required to maintain and protect the software baseline for all locally maintained software components.

e. Includes all capabilities required to produce, deliver and document corrections, modifications, adaptations, and enhancements of existing software for the TKUP.

f. Includes the capabilities required for the adaptation of third party software for use in TKUP.

5.2.3 Software Configuration Management

The software maintenance function shall provide the following Software Configuration Management (SCM) capabilities:

a. Software change control and configuration status accounting.

b. Software Quality Assurance (QA).

c. Software tools for the automation of SCM functions.

d. Maintenance of all final design source code and executable code.

e. Facilities to store the latest versions of software for the TKUP in a manner secure from alteration by malicious tampering or destruction by fire, flood, or other disaster.

5.2.4 Software Baseline

For all software components that are not maintained by external parties (i.e. operating system, COTS software products), the software maintenance function shall include all hardware and development software that is required to generate all system software components from the source code that is maintained by the SCM function for that component.

5.2.5 Tracking System

The software maintenance function shall provide a tracking system to report, track, and authorize all software maintenance activities.

5.2.6 ADPE Equipment Requirements

The software maintenance function shall:

a. Contain equipment identical to the equipment performing the same functions in the operational systems.

b. Provide for testing of failover software and procedures for operational systems for which failover functions exist.

5.2.7 Simulators

a. Where necessary to meet software maintenance requirements, the software maintenance function shall include simulator equipment to provide realistic equipment responses.

b. As a minimum, simulators shall be provided in the following cases:

    1. Equipment simulators that provide realistic command responses and status input for equipment, for cases where the actual equipment is not available to the software maintenance function.

    2. Interface simulators that provide accurate simulation of external interfaces, including the message protocol and message formats defined for each interface, for cases where the actual interface equipment is not available to the software maintenance function.

SECTION 6. RELIABILITY, MAINTAINABILITY, AND AVAILABILITY

This section specifies the reliability, maintainability, and availability (RMA) requirements for the TKUP. Two categories of availability requirements are defined: inherent availability and operational availability.

6.1 Reliability

The measure of reliability for the TKUP shall be the mean-time-between-failures (MTBF). Acceptable MTBF for the TKUP is not specifically identified; however, MTBF contributes to the required inherent availability for the system. Predictive methods for determining MTBF are specified.

6.1.1 MTBF Definition

The MTBF for any identified equipment group is defined as the life cycle period of the equipment divided by the predicted number of failures.

6.1.2 MTBF, Required Methods

a. The MTBF for any equipment group shall be determined during the initial stages of system design in accordance with the parts count reliability prediction method of MIL-HDBK-217, Reliability Prediction of Electronic Equipment.

b. The MTBF for any equipment group shall shift to the parts stress analysis prediction method, or other reliability modeling technique approved by NASA, at the time when a firm, detailed parts list is available for the equipment group.

6.2 Maintainability

Maintainability is characterized by the mean-time-to-repair (MTTR) and the maximum time to repair. Both include the corrective maintenance time, but not logistics and administrative delays inherent to the maintenance process. Logistics delays include the time required to provide replacement units at the failure location (replacement units are presumed to be available on-site). Administrative delays include the time required for maintenance personnel and test equipment to arrive at the failure location. Maintainability also includes requirements for fault isolation. Acceptable MTTR and maximum time to repair for the TKUP are not specifically identified; however, they contribute to the required inherent availability for the system.

6.2.1 MTTR Definition

MTTR, as a measure of maintainability of an individual equipment group, is defined as the sum of corrective maintenance times, to include Level-1 maintenance only, divided by the total number of failures within that equipment group during a particular interval under stated conditions.

6.3 Availability

6.3.1 Inherent Availability

Inherent availability (A_i) is a measure of the probability that a system or equipment group, when used under stated conditions in an ideal support environment (i.e., using available tools, spares, and personnel) will operate within specifications at any time. It excludes preventive maintenance actions; logistics supply time, and administrative downtime. A_i is defined for non-redundant equipment paths; consequently, the A_i of an equipment group is defined per the expression,

$$A_i = \frac{MTBF}{MTBF + MTTR},$$

for any period of 10,000 hours. Any loss of availability due to loss of WSC or GRGT facility services will not be counted.

Design of TKUP shall ensure the inherent availability requirements specified in 530-RSD-WSC, *Requirements Specification for the White Sands* Complex, Section 13, Reliability/ Maintainability/Availability (R/M/A) Requirements, are not reduced.

6.3.2 Operational Availability

The operational availability (A_o) for any system is a measure of the percentage of time the system is available to support the service or support function for which the system is intended, and to perform that function within all specifications defined by these functional and performance requirements.

The computation of operational availability for all systems will use the following formula:

$$A_o = \frac{Time\ Service\ is\ Available}{Time\ Service\ is\ Available + Time\ Service\ is\ Not\ Available}$$

The time service is available is measured over a contiguous 10,000 hour interval except that any loss of availability due to loss of facility services such as power or air conditioning will not be counted. The time service is not available includes all times service is not available due to corrective maintenance downtime, administrative downtime, logistics supply downtime, and preventive maintenance downtime. It also includes all times that the system is supporting operational service, but is not performing per all requirements defined by this specification.

In predicting or computing the operational availability for any function on which a Government provided, inter-facility redundant carrier service is dependent, it will be assumed that the operational availability of the carrier service itself is equal to or better than 0.9999. Redundant paths may be used in achieving the A_o requirements.

Design of TKUP shall ensure the operational availability requirements specified in 530-RSD-WSC, *Requirements Specification for the White Sands* Complex, Section 13, Reliability/ Maintainability/Availability (R/M/A) Requirements, are not reduced.

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SECTION 7. DESIGN AND CONSTRUCTION

7.1 General Requirements

a. System Life Expectancy.
   1. The TKUP shall be designed to have a useful, supportable life of fifteen (15) years.
   2. The TKUP shall meet all the requirements of this specification over the entire 15 year period.

b. Operational Convenience.
   1. Doors and Displays. All TKUP hardware shall comply with the electromagnetic interference (EMI) requirements of Section 7.7 without using rack front doors or hiding controls and displays.
   2. Accessibility. All TKUP controls and displays shall be fully accessible during setup and normal operation.

c. Equipment of New Design.
   1. Chassis, Subsystems and Systems. All chassis, subsystems and systems of new design or significantly modified design shall be designed and constructed to comply with the requirements of STDN-SPEC-4, *GSFC General Requirements for STDN Electronic Equipment*, or best commercial practice.
   2. Connectors, Cables and Wires. Connectors, cable, wires and other materials listed in STDN-SPEC-8, *GSFC Specification for Electronic Equipment Installation Materials*, or that complies with best commercial practice, shall be used in the design and construction of TKUP equipment.

d. COTS and Modified COTS Equipment.
   1. COTS and modified COTS equipment shall satisfy the requirements of S-323-P-5A, *Quality Assurance Requirements for Standard Industrial Equipment*.

7.2 Environmental, Operating

7.2.1 Temperature

a. TKUP hardware shall be capable of operating at interior ambient temperatures between 59 degrees Fahrenheit (F) and 95 degrees F.

b. TKUP hardware shall be capable of operating at interior ambient temperatures between 32 degrees Fahrenheit (F) and 104 degrees F for duration of at least one hour.

7.2.2 Relative Humidity

TKUP hardware shall be capable of operating at a relative humidity of up to 95%, at ambient temperatures identified in Section 7.2.1.

7.3 Modularity and Extensibility

The following requirements are to be met to postpone obsolescence of all TKUP components.

a. The TKUP shall use modular hardware and software that allows changes and enhancements to be performed in a straightforward manner.
b. The hardware shall use functional modules that allow replacement to improve performance, reliability or for other reasons.
c. The software shall use documented modules and a structure that allows maintenance and enhancements.

7.4 Power Source

a. TKUP equipment shall be designed to operate from existing UPS electrical power provided by the ground terminal facility.
b. TKUP equipment shall be designed to operate from electrical power output from the UPS electrical power provide by the ground terminal facility.

7.5 Safety

The TKUP design shall meet all applicable safety requirements of NASA Procedures and Guidelines (NPG) 8715.3, *NASA Safety Manual*.

7.6 Equipment Integration

7.6.1 Electronic Equipment Racks

TKUP equipment shall be mounted in electronic equipment racks that conform to the interface requirements of EIA-390, *Racks, Panels and Associated Equipment*.

7.6.1.1 Panel Size

Racks shall accommodate standard 19-inch EIA equipment panels.

7.6.1.2 Mounting Holes

Racks shall include tapped panel mounting holes.

7.6.1.3 EMI Racks and Filtering

EMI racks and filtering shall be used as required.

7.6.2 Cabling and Connectors

System and subsystem performance shall be met with installation cabling included.

7.6.3 Bonding and Grounding

All TKUP equipment shall comply with the bonding and grounding requirements of STDN 270.7, *GSFC Specification Grounding System Requirements for STDN Stations*.

7.7 Electromagnetic Interference

All TKUP equipment shall meet the requirements of FCC Rules CFR 47, Part 15, Subpart B, Sections 15.107 and 15.109 for Class A or B conducted and radiated emission levels.

7.8 Software

a. The TKUP software development shall be performed in accordance with NPD 2820.1, NASA Software Policies.

b. Software Engineering Institute (SEI) Capability Maturity Model (CMM) Level 3 standards, or above, shall be applied to all software development activities.

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SECTION 8. SECURITY

8.1 Information Technology Security

8.1.1 Information Technology Security Description

Information Technology (IT) security provides for the safeguard of classified or sensitive information and material processed by or in Information Technology Systems (ITS) through ensuring system/data confidentiality, integrity and availability. NPR 2810.1, NASA Security of Information Technology and WSC-PLN-0024, Information Technology Systems Security Plan (ITSSP) for the White Sands Complex provide guidelines to define the information categories for the SN ground segment and the requirements for risk management and security maintenance.

8.1.2 IT Security Requirements

The TKUP IT Security requirements shall comply with:

a. Mission requirements of NPR 2810.1, NASA Security of Information Technology.

b. NITR 2810-2, *Information Technology (IT) System Security Requirements* (including the referenced National Institute of Standards and Technology (NIST) Special Publications).

c. WSC-PLN-0024, Information Technology Systems Security Plan (ITSSP) for the White Sands Complex.

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SECTION 9. TKUP EQUIPMENT DOCUMENTATION

Documentation to be developed in accordance with this TKUP specification shall be numbered in accordance with the numbering system specified in STDN 102, ST*DN Documentation System*. Technical manuals shall be prepared in accordance with STDN-SPEC-1, S*pecification Preparation and Acceptance of Technical Manuals*. Operations documents shall be prepared in accordance with STDN 102.1, *Standard for Preparation of STDN Operations Documents*. Interface control documents shall be prepared in accordance with STDN 102.8, *Handbook for Interface Control Documents for Non-Project Related Ground Facilities.*

9.1 Documentation Automation

All documents prepared for SN ground systems including new TKUP documentation shall be compatible with the requirements of the NASA Integrated Automated Documentation Program.

9.2 Drawings

a. TKUP drawings shall be prepared in accordance with STDN SPEC-9, *Specification Drawing System*, and S-572-P-3B, *Engineering Drawing Standards and Specifications*.

b. All TKUP drawings shall represent the TKUP systems as built and installed.

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APPENDIX A. ANTENNA AUTOTRACK AM CHARACTERISTICS

A.1 AM Signal Characteristics

a. The TDRS amplitude modulates the Customer return signal with an SA antenna autotrack error signal. Two error signals are generated onboard the TDRS, one from each channel of a two-axis monopulse system, to closed-loop track each SA antenna.

b. The two error signals, corresponding to the two SA antenna gimbal axes, are time-division multiplexed to form a single error signal that switches between error channels every 32 ms.

c. The error signal is BPSK-modulated by a 2048-bit sequence (generated by Manchester [Biϕ-L] encoding a 1024-chip PN code). Since the bit rate is 2 kbps, the sequence repeats every 1.024 seconds.

d. The PN epoch is coincident with the first millisecond of the KSA inner gimbal axis error signal interval.

e. The BPSK-modulated error signal amplitude modulates the return signal with a modulation index that varies between 0 (during autotracking) and 0.10 (during autotrack pull-in). This signal can be analytically expressed as follows:

$$V_r \cos [\omega_r t + \theta_r(t)] \bullet [1 + M_e(t)] \bullet [1 + N(t)], \text{ where}$$

V_r = Return signal voltage.

ω_r = Return signal Ku-band or Ka-Band carrier frequency (radians/second).

$\theta_r(t)$ = Return signal phase modulation and phase offset.

$M_e(t)$ = Modulation index, $0 \le |M_e(t)| \le 0.10$.

$N(t)$ = Incidental AM.

The modulation index, $M_e(t)$, can be expressed as follows:

$$M_e(t) = \sum_n (\Delta V_n / V_r)\, P_s(t - nT_s) \bullet \sum_m P_c(t - mT_c), \text{ where}$$

ΔV_n = Sample of error voltage on n^{th} channel (n = 1 or 2).

Vr = Return channel voltage

$-M \le (\Delta V_n / V_r) \le +M$, where M = 0.10 = Maximum modulation index.

$P_s(t - nT_s)$ = 1 for $nT_s \le t \le (n + 1) T_s$

= 0 elsewhere

= Time sampling of two error channels with 50% duty factor.

$P_c(t - mT_c)$ = A_M for $mT_c \le t \le (m + 1) T_c$ where $A_M = \pm 1$

= Manchester-encoded PN code on error signal.

T_c = chip time = 0.5 msec ±0.03% (coherent with telemetry data).

T_s = switching time = 32 msec ±0.03% (coherent with telemetry data).

Definition of Autotrack Acquisition Time

"Autotrack acquisition time" is defined as the interval between the following start and stop times:

Start time: When the KuSAR or KaSAR Customer signal is received at the input of the KSA HDR HWCI equipment.

Stop time: When autotrack acquisition occurs.

Definition of Autotrack Acquisition

"Autotrack acquisition" is defined to have occurred when the antenna autotrack error signals maintain the TDRS SA antenna boresight axes in continuous alignment with the Customer platform with sufficient accuracy to provide the autotrack-mode EIRP specified for the KuSAF service in Table 7-2 of 450-SNUG or KaSAF service in Table 8-2 of 450-SNUG.

A.2 Customer Dynamics Constraints

The SGLT, in conjunction with a TDRS, will be capable of autotracking a KuSAR and KaSAR Customer platform with the following constraints:

- KuSAR and KaSAR Angular Velocity: ≤ 0.0135°/sec, where "angular velocity" is defined as the time rate-of-change of the angle of the SA antenna on the TDRS.
- KuSAR Ephemeris Uncertainty for Primary Field of View: ≤ ± 4.5 sec, where the ephemeris uncertainty is assumed to be uniformly distributed along the Customer platform orbital track.
- KuSAR Ephemeris Uncertainty for Extended Elliptical Field of View (F8-F10 spacecraft only): ≤ ± 3.2 sec, where the ephemeris uncertainty is assumed to be uniformly distributed along the Customer platform orbital track.
- KaSAR Ephemeris Uncertainty: ≤ ± 2.0 sec, where the ephemeris uncertainty is assumed to be uniformly distributed along the Customer platform orbital track.

APPENDIX B. 225 MHZ CHANNEL SIGNAL DISTORTIONS

B.1 Customer Signal Distortion Constraints For 8-PSK and SQPSK with TPC and/or LDPC

The Customer signal distortion constraints for TPC and/or LDPC services are defined in Table B-1.

B.2 TDRS Ku-to-Ku-Band RF Processing For Ku-Band SA Return Data Service (TDRS F1-F7 and TDRS F8-F10 Spacecraft)

This section defines how the TDRS receives a KuSAR signal from the Customer platform, downconverts it to another Ku-band frequency, and relays it to the ground terminals via the SGL downlink.

B.2.1 Ku-Band Frequencies

The TDRS receives a KuSAR signal from a Customer platform at the Ku-band center frequency of 15.0034 GHz (This frequency does not include the effects of Doppler shift).

B.2.2 225 MHz Channel Parameters

The TDRS provides the KuSAR 225 MHz channel parameters as defined in Table B-2. Table B-2 addresses the TDRS F1-F7 spacecraft and the TDRS F8-F10 spacecraft.

B.2.3 225 MHz Channel Signal and Distortion Requirements

The TDRS meets the KuSAR 225 MHz channel signal and distortion requirements specified in Table B-3. Table B-3 addresses the TDRS F1-F7 spacecraft and the TDRS F8-F10 spacecraft.

B.2.4 Downconversion from Ku-Band to Ku-Band

The TDRS downconverts the KuSAR signal from Ku-band to the Ku-band frequency as defined Table B-3 Center Frequency Output from TDRS parameter.

Table B-1. 225 MHz Data Service Customer Signal Distortion Constraints For 8-PSK and SQPSK with TPC and/or LDPC

Parameter (Notes 1,2,3)	Constraint (Note 1)
Minimum channel state symbol transition density (Note 4)	≥ 128 randomly distributed channel state symbol transitions within any sequence of 512 channel state symbols
Consecutive I-channel or Q-channel channel state symbols without a state transition (Note 4)	≤ 64 channel state symbols
Channel state symbol asymmetry (peak) (Note 4)	≤ ± 3 percent
AM/AM	0.43 dB/dB
Channel state symbol jitter and jitter rate (Note 4)	≤ 0.2 percent
Phase imbalance	
SQPSK	≤ ± 3 degrees
8-PSK	≤ ± 2 degrees
Gain imbalance	≤ ± 0.25 dB
Phase nonlinearity (applies for all types of phase nonlinearities) (peak-to-peak)	≤ 6 degrees over ± 80 MHz
Gain flatness (peak-to-peak)	≤ 0.6 dB over ± 80 MHz
10. Gain slope	≤ 0.1 dB/MHz over ± 80 MHz
11. AM/PM	≤ 6 degrees/dB
12. Noncoherent frequency stability (peak) (Notes 5,6)	
± 54 kHz Customer oscillator frequency uncertainty	
1-sec observation time	≤ 3×10^{-9}
Lifetime	≤ 1.1×10^{-5}
Incidental AM (peak)	
For open-loop pointing at frequencies ≥ 100 Hz	≤ 5 percent
For autotrack performance	
At frequencies: 10 Hz – 10 kHz	≤ 3 percent
At frequencies: 10 Hz – 2 kHz	≤ 0.6 percent
Spurious PM	≤ 2 degrees (1 kHz to 400 MHz) ≤ -30 dBc/Hz (individual spurious PM spurs from 1 Hz to 1 kHz)

Table B-1. 225 MHz Data Service Customer Signal Distortion Constraints For 8-PSK and SQPSK with TPC and/or LDPC (Cont'd)

Parameter (Notes 1,2,3)	Constraint (Note 1)
Minimum 3-dB bandwidth prior to power amplifier	≥ 2 times maximum channel baud rate (Note 8)
Phase noise	
1 Hz – 10 Hz	≤ 50.0 degrees rms
10 Hz – 100 Hz	≤ 20.0 degrees rms
100 Hz – 1 kHz	≤ 3.6 degrees rms
1 kHz – 400 MHz	≤ 2.0 degrees rms
In-band spurious outputs, where in-band bandwidth is twice the maximum channel symbol rate	≤ -30 dBc
Out-of-band emissions	See Appendix D of 450-SNUG, for allowable limits on out-of-band emissions, including spurs
I/Q channel state symbol skew (peak) (Note 4)	≤ 3 percent
Axial ratio	≤ 3 dB
Data rate tolerance	≤ ± 1.0 percent
I/Q power ratio tolerance	≤ ± 0.4 dB
Permissible P_{rec} variation (without reconfiguration GCMR from Customer MOC) (Note 7)	≤ 12 dB during service period
Permissible rate of P_{rec} variation	≤ 10 dB per second
Maximum P_{rec}	-149.2 dBW

NOTES

1. The definitions and descriptions of the Customer constraints are provided in 450-SNUG, Appendix E.
2. When a constraint value is listed for a channel state symbol rate range and coding is used, the channel state symbol rate includes the encoding bits. (See Note 4 below for the definition of channel state symbol)
3. These signal constraints apply to the KuSAR 225 MHz channel.
4. Both 8-PSK and QPSK physically have I and Q channels that have signal level changes. For 8-PSK, the signal level for an individual I or Q channel can have any one of four possible signal levels at a given moment. For SQPSK, the signal level for an individual I or Q channel can have any one of two possible signal levels at a given moment. For 8-PSK and SQPSK, a channel state symbol is defined as the signal level status of an individual I or Q channel.

Table B-1. 225 MHz Data Service Customer Signal Distortion Constraints For 8-PSK and SQPSK with TPC and/or LDPC (Cont'd)

Parameter (Notes 1,2,3)	Constraint (Note 1)
NOTES	
5. The frequency stability requirements are valid at any constant temperature (± 0.5ºC) in the range expected during the mission. At a minimum, a temperature range of -10°C to +55°C is considered.	
6. All KuSAR 225 MHz Data Services are noncoherent and require a Customer transmit frequency uncertainty of ± 54 kHz.	
7. The minimum SHO EIRP should reflect the minimum P_{rec} expected over the service period, where the P_{rec} can exceed this minimum by no more than 12 dB. An actual Customer P_{rec} value that is 12 dB greater than the minimum may cause nonacquisition.	
8. Baud Rate is defined as the rate at which the phase of the carrier wave is changed by the modulating signal.	

Table B-2. TDRS KuSAR 225-MHz Channel Parameters

Parameter	TDRS F1-F7 Spacecraft 225-MHz Channel Constraints	TDRS F8-F10 Spacecraft 225-MHz Channel Constraints
Receive antenna location	TDRS F1-F7 spacecraft	TDRS F8-F10 spacecraft
Polarization (selectable)	Right Hand Circular (RHC) and Left Hand Circular (LHC)	RHC and LHC
Axial ratio (over 3-dB beamwidth)	Program Track, Primary: 1.5 dB LEO Program Track: 1.0 dB Program Track, Extended: 1.5 dB Autotrack: 1.0 dB	Program Track, Primary: 1.5 dB LEO Program Track: 1.0 dB Program Track, Extended: 1.5 dB Autotrack: 1.0 dB
Field of View (FOV)		
LEO program track		
Beam shape	Conical	Circular
FOV	±10.5°	±10.5°

Table B-2. TDRS KuSAR 225-MHz Channel Parameters (Cont'd)

Parameter	TDRS F1-F7 Spacecraft 225-MHz Channel Constraints	TDRS F8-F10 Spacecraft 225-MHz Channel Constraints
Program track		
Primary		
Beam shape	Rectangular	Rectangular
North-south[1,2]	±28.0°	±28.0°
East-west[1,2]	±22.0°	±22.0°
Extended		
Beam shape	N/A	Elliptical
Elevation[1]	N/A	±30.5°
Azimuth[1]	N/A	
Inboard	N/A	24.0° east-west
Outboard	N/A	76.8° east-west
Autotrack		
Primary		
Beam shape	Rectangular	Rectangular
North-south[1,2]	±28.0°	±28.0°
East-west[1,2]	±22.0°	±22.0°
Extended		
Beam shape	N/A	Elliptical
Elevation[1]	N/A	±30.5°
Azimuth[1]	N/A	
Inboard	N/A	22.0° east-west
Outboard	N/A	76.8° east-west

NOTES

1. TDRS spacecraft orbit normal coordinates.
2. In the TDRS spacecraft orbit-normal coordinate system, "north-south" refers to elevation and "east-west" refers to azimuth.

Table B-3. TDRS KuSAR 225-MHz Channel Signal & Distortion Constraints

Parameter	TDRS F1-F7 and TDRS F8-F10 Spacecraft 225-MHz Service Requirements[1]
Center frequency	
Input to TDRS	15.0034 GHz
Output from TDRS	Dedicated: 13528.4 MHz ± 2.4 MHz Composite: 13928.4 MHz ± 2.4 MHz
Gain flatness	≤ 1.2 dB (peak-to-peak) over ±80 MHz about the center frequency
Phase nonlinearity (all types)	≤ 12° (peak-to-peak) over ±80 MHz about the center frequency
AM/AM	> 0.6 dB/dB (typical performance is 0.77 dB/dB)
AM/PM	≤ 6°/dB (typical performance is 2.37°/dB)
3-dB RF bandwidth	≥ 225 MHz (typical performance is ≥ 240 MHz)
Spurious PM	≤ 0.6° rms between 100 Hz and 112.5 MHz from the center frequency
Spurious outputs	≤ -30 dBc (within 3-dB RF bandwidth)
Incidental AM	≤ 1% (within 3-dB RF bandwidth)
Phase noise[2]	
1 Hz to 10 Hz	≤ 50.2° rms
10 Hz to 100 Hz	≤ 10.6° rms
100 Hz to 1 kHz	≤ 2.7° rms
1 kHz to 150 MHz	≤ 3.2° rms
1 kHz to 400 MHz	N/A

NOTES

1. Parameters are measured at the Ku-band SGL antenna output of the TDRS. Contributions from only the TDRS F8-F10 spacecraft are included, except for carrier phase noise, which also includes contributions from the Customer platform (see note 2 below).
2. Phase noise is specified as the result of contributions from both the Customer platform and the TDRS.

   For the 225-MHz service, the Customer platform contribution is:

   a. 1 Hz to 10 Hz: ≤ 50.0° rms.
   b. 10 Hz to 100 Hz: ≤ 10.0° rms.
   c. 100 Hz to 1 kHz: ≤ 2.0° rms.
   d. 1 kHz to 150 MHz: ≤ 2.0° rms

B.3 TDRS Ka-to-Ku-Band RF Processing For Ka-Band SA Return Data Service (TDRS F8-F10 Spacecraft Only)

This section describes how the TDRS F8-F10 spacecraft receives a KaSAR signal from the Customer platform, downconverts it to Ku-band, and relays it to the ground terminal via the SGL downlink.

B.3.1 Ka-Band Frequencies

The TDRS F8-F10 spacecraft receives a KaSAR signal from a Customer platform at the Ka-band center frequencies specified below (these frequencies do not include the effects of Doppler shift). The 225-MHz KaSAR service supports two frequency plans: the TDRS F8-F10 and the SNIP/SFCG frequencies.

B.3.1.1 TDRS F8-F10 Frequencies For 225-MHz KSAR Service

The TDRS F8-F10 spacecraft tunes to any of the following center frequencies:

a. Minimum: 25.2534 GHz.
b. Maximum: 27.4784 GHz.
c. Step size: ≤ 25-MHz (that is, ≥ 90 different frequencies).

B.3.1.2 Space Network Interoperability Panel/Space Frequency Coordination Group Frequencies For 225-MHz KSAR Service

The TDRS F8-F10 spacecraft supports the following SNIP/SFCG center frequencies:

a. 25.60 GHz.
b. 25.85 GHz.
c. 26.10 GHz.
d. 26.35 GHz.
e. 26.60 GHz.
f. 26.85 GHz.
g. 27.10 GHz.
h. 27.35 GHz.

B.3.2 225 MHz Channel Parameters

The TDRS F8-F10 spacecraft provides the KaSAR 225 MHz channel parameters as defined in Table B-4.

Table B-4. TDRS F8-F10 KaSAR 225-MHz Channel Parameters

Parameter	225-MHz Channel Requirements
Receive antenna location	TDRS F8-F10 spacecraft
Polarization (selectable)	RHC and LHC
Axial ratio (over 3-dB beamwidth)	≤ 1.0 dB
FOV	
LEO program track	
Beam shape	Circular
FOV	±10.5°
Program track	
Primary	
Beam shape	Rectangular
North-south[1,2]	±30.0°
East-west[1,2]	±22.0°
Extended	
Beam shape	Elliptical
Elevation[1]	±30.5°
Azimuth[1]	
Inboard	22.0° east-west
Outboard	76.8° east-west
Autotrack	
Primary	
Beam shape	Rectangular
North-south[1,2]	±30.0°
East-west[1,2]	±22.0°
Extended	
Beam shape	Elliptical
Elevation[1]	±30.5°
Azimuth[1]	
Inboard	22.0° east-west
Outboard	76.8° east-west

NOTES

1. TDRS F8-F10 spacecraft orbit normal coordinates.
2. In the TDRS F8-F10 spacecraft orbit-normal coordinate system, “north-south” refers to elevation and “east-west” refers to azimuth.

B.3.3 225 MHz Channel Signal and Distortion Requirements

The TDRS F8-F10 spacecraft meets the KaSAR 225 MHz channel signal and distortion requirements defined in Table B-5.

Table B-5. TDRS F8-F10 Spacecraft KaSAR 225-MHz Channel Signal & Distortion Constraints

Parameter	225-MHz Service Constraint[1]
Center frequency	
Input to TDRS	As specified in section B.3.1 above
Output from TDRS	SNIP, SFCG, Dedicated: 13525.0 MHz ± 2.4 MHz SNIP, SFCG, Composite: 13925.0 MHz ± 2.4 MHz TDRS F8-F10, Dedicated: 13528.4 MHz ± 2.4 MHz TDRS F8-F10, Composite: 13928.4 MHz ± 2.4 MHz
Gain flatness	≤ 1.2 dB (peak-to-peak) over ±80 MHz about the center frequency[3]
Phase nonlinearity (all types)	≤ 12° (peak-to-peak) over ±80 MHz about the center frequency[4]
AM/AM	> 0.6 dB/dB (typical performance is 0.77 dB/dB)
AM/PM	≤ 6°/dB (typical performance is 2.37°/dB)
3-dB RF bandwidth	≥ 225 MHz
Spurious PM	≤ 2.24° rms between 100 Hz and 112.5 MHz from the center frequency
Spurious outputs	≤ -30 dBc (within 3-dB RF bandwidth)
Incidental AM	≤ 1% (within 3-dB RF bandwidth)
Phase noise[2]	
1 Hz to 10 Hz	≤ 50.2° rms
10 Hz to 100 Hz	≤ 10.9° rms
100 Hz to 1 kHz	≤ 3.1° rms
1 kHz to 150 MHz	≤ 2.7° rms
1 kHz to 400 MHz	N/A

Table B-5. TDRS F8-F10 Spacecraft KaSAR 225-MHz Channel Signal & Distortion (Cont'd)

Parameter	225-MHz Service Constraint[1]
NOTES	
1. Parameters are measured at the Ku-band SGL antenna output of the TDRS F8-F10 spacecraft. Contributions from only the TDRS F8-F10 spacecraft are included, except for carrier phase noise, which also includes contributions from the Customer platform (see note 2 below). 2. Phase noise is specified as the result of contributions from both the Customer platform and the TDRS F8-F10 spacecraft. For the 225-MHz service, the Customer platform contribution is: a. 1 Hz to 10 Hz: ≤ 50.0° rms. b. 10 Hz to 100 Hz: ≤ 10.0° rms. c. 100 Hz to 1 kHz: ≤ 2.0° rms. d. 1 kHz to 150 MHz: ≤ 2.0° rms. 3. Gain flatness is specified as the residual RF amplitude variation from linearity after subtracting the linear and parabolic components lying within the equalization bounds corresponding to the amplitude equalization bounds specified in the following figure in 405-TDRS-RP-SY-001: 225-MHz service: Figure 6-12 (KuSAR). 4. Phase nonlinearity is specified as the residual RF phase variation from linearity after subtracting the cubic and parabolic components lying within the equalization bounds corresponding to the phase equalization bounds specified in the following figure in 405-TDRS-RP-SY-001: 225-MHz service: Figure 6-9 (KuSAR), or the equivalent group delay equalization bound specified in Figure 6-10 (KuSAR).	

B.3.4 Downconversion from Ka-Band to Ku-Band

The TDRS F8-F10 spacecraft downconverts the KaSAR signal from Ka-band to the Ku-band frequency defined in Table B-5, Center Frequency Output from TDRS parameter.

B.3.5 Transmission via Ku-Band Space-Ground Link Downlink

The TDRS F8-F10 spacecraft transmits the KaSAR signal to the WSC ground segment via the Ku-band SGL.

APPENDIX C. TDRSS KSA RETURN SERVICES FUNCTIONAL CONFIGURATIONS

The configurations in this appendix provide a graphical depiction of all of the service configurations that the receiver equipment in Section 4 are to support.

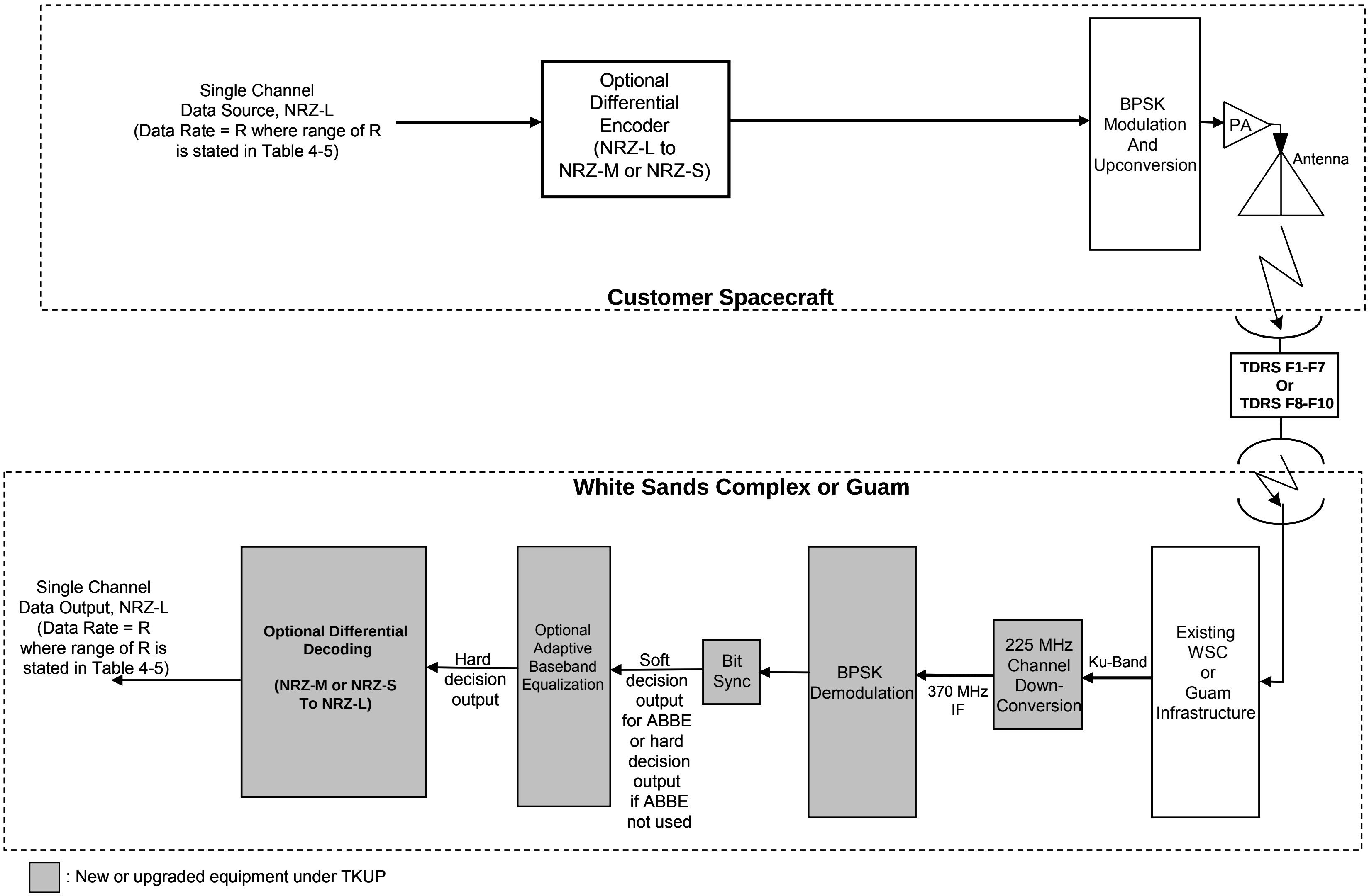


Figure C-1. Uncoded BPSK, Single Channel Configuration

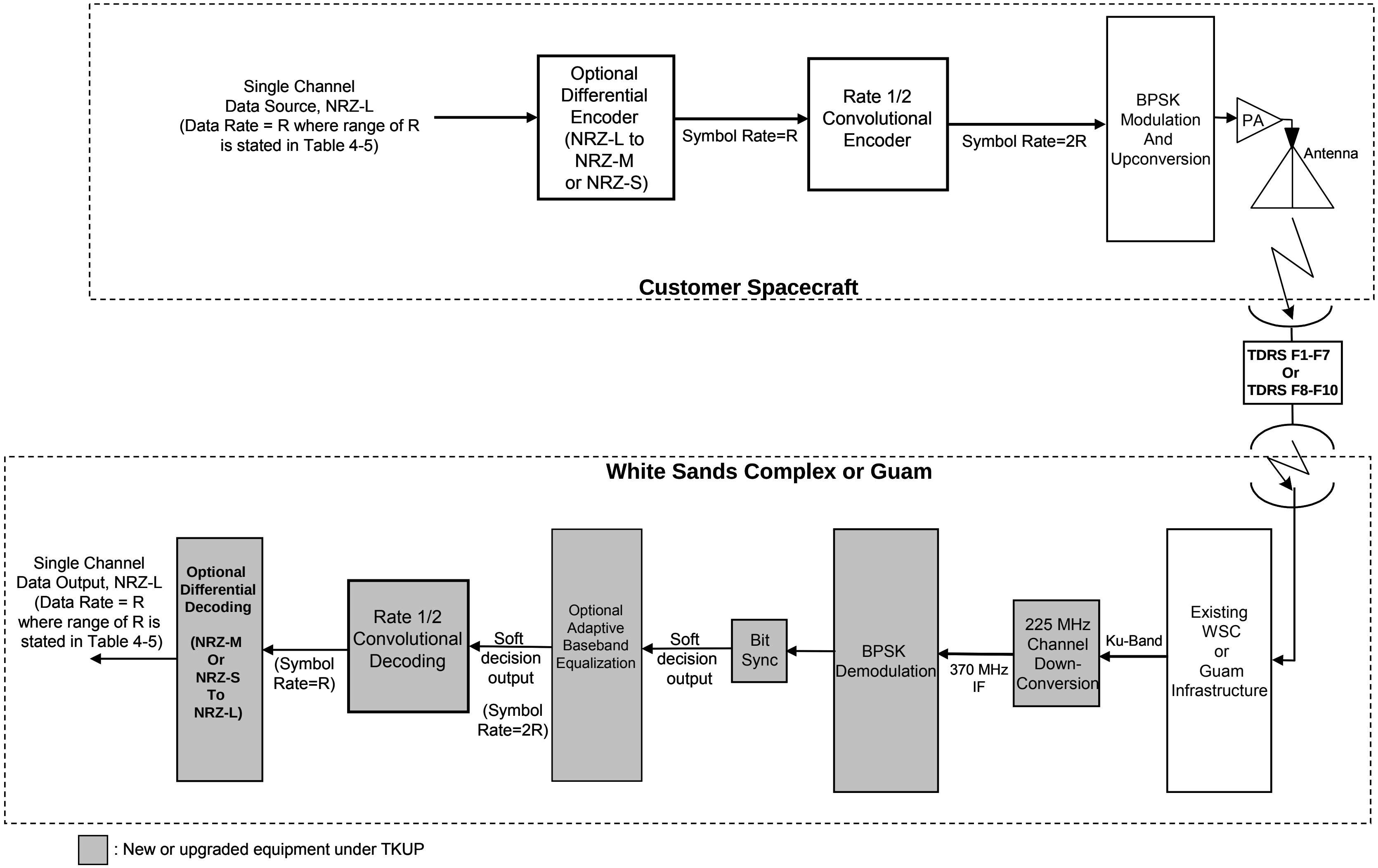
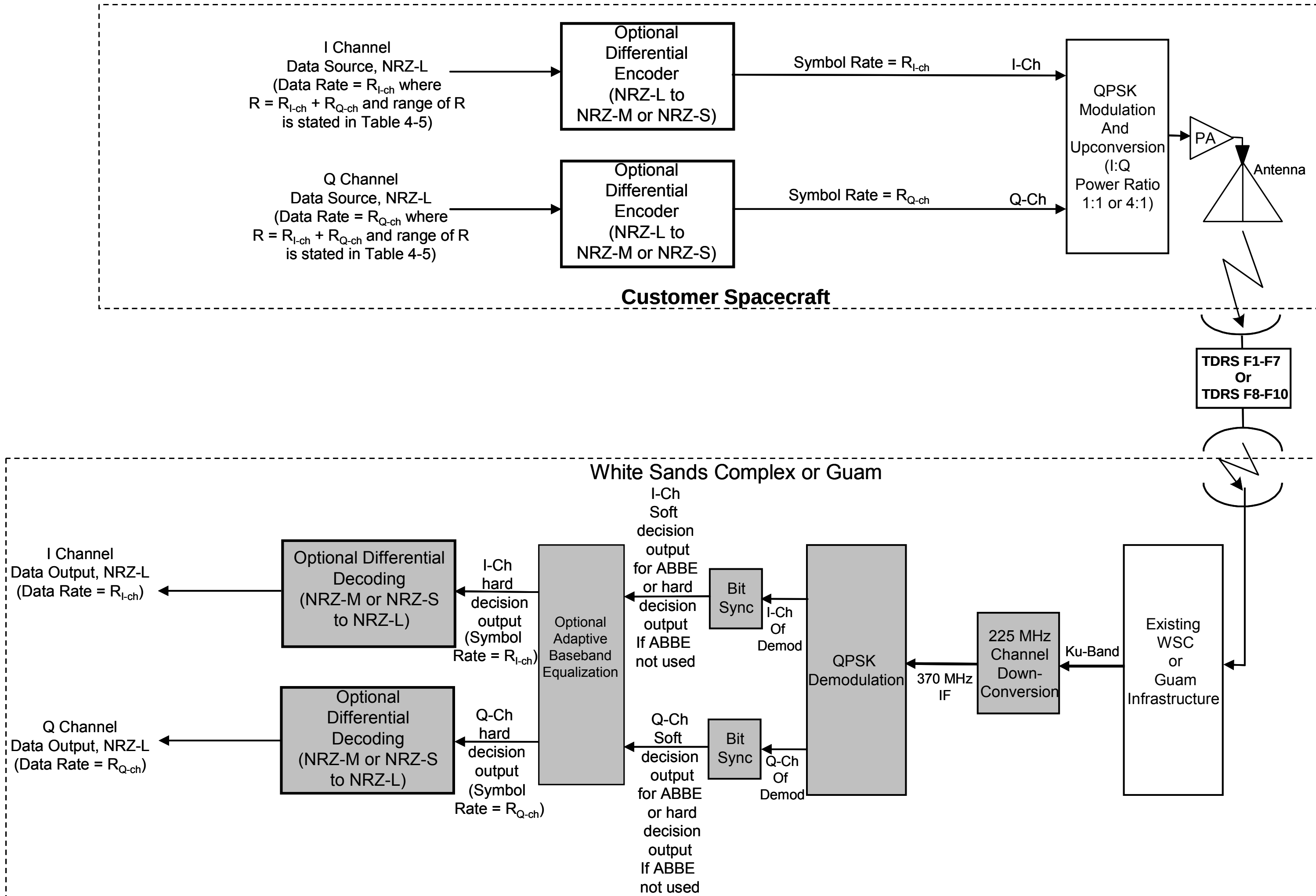


Figure C-2. Coded BPSK, Single Channel Configuration



: New or upgraded equipment under TKUP

Figure C-3. Uncoded QPSK, Dual Channel Configuration

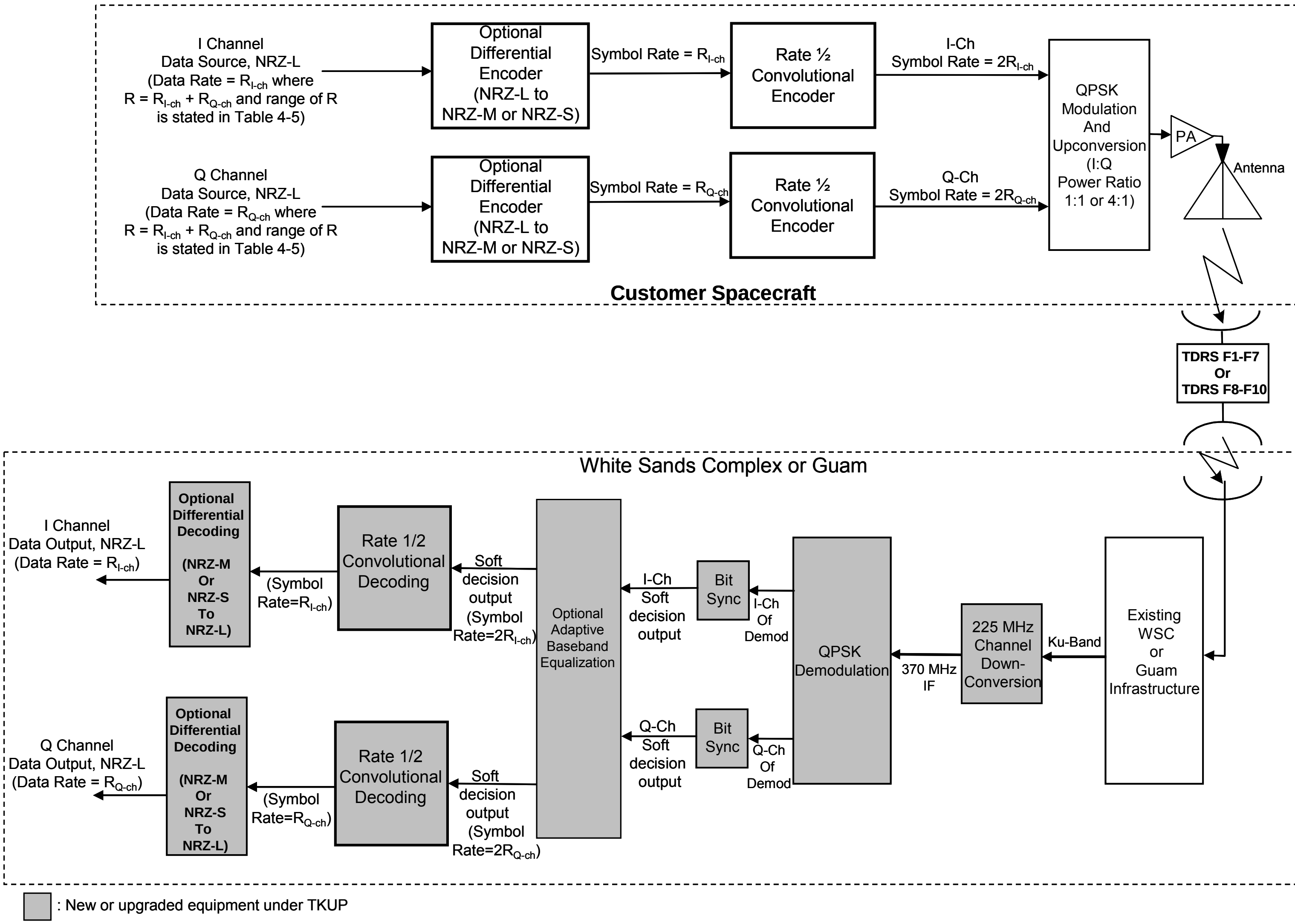
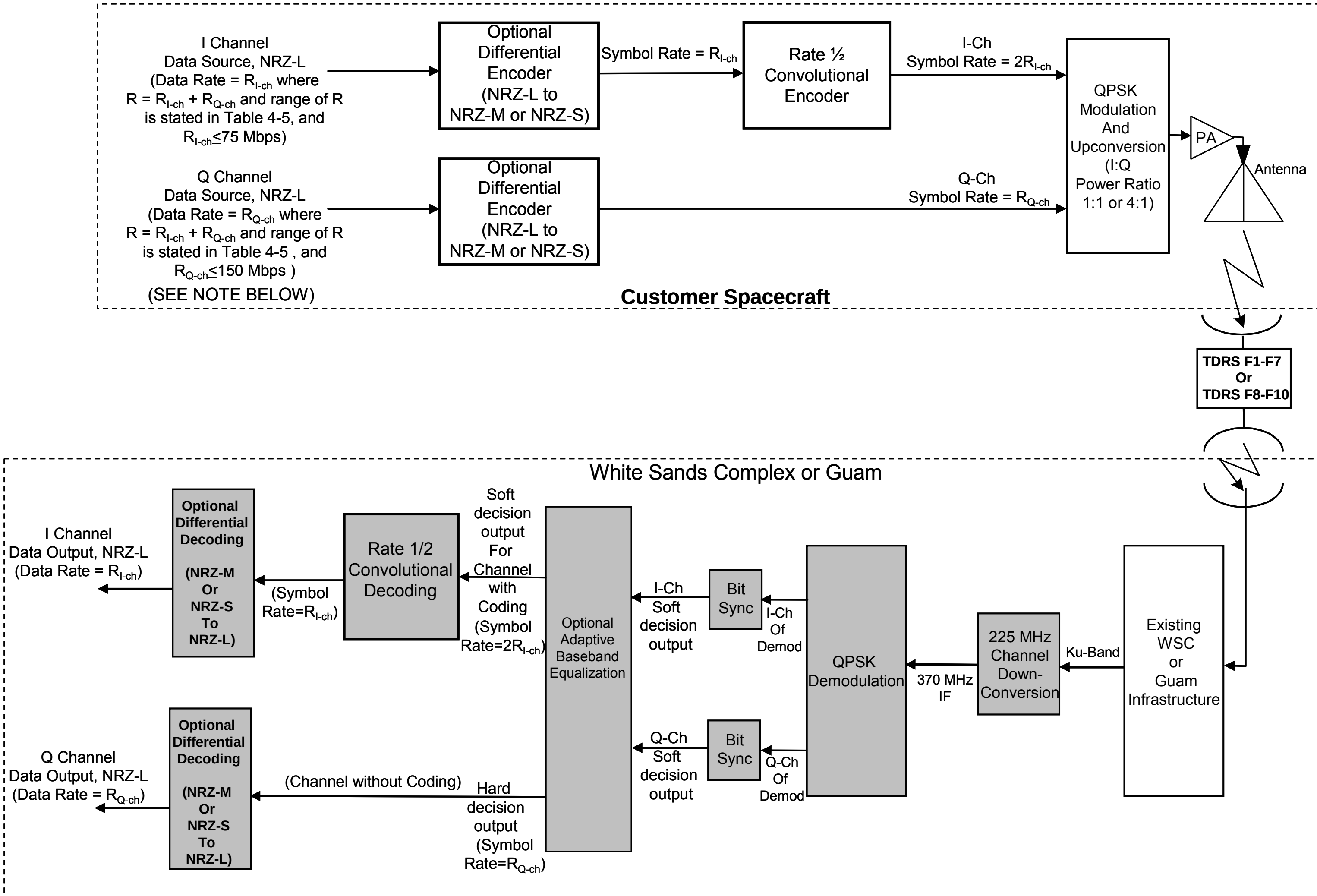


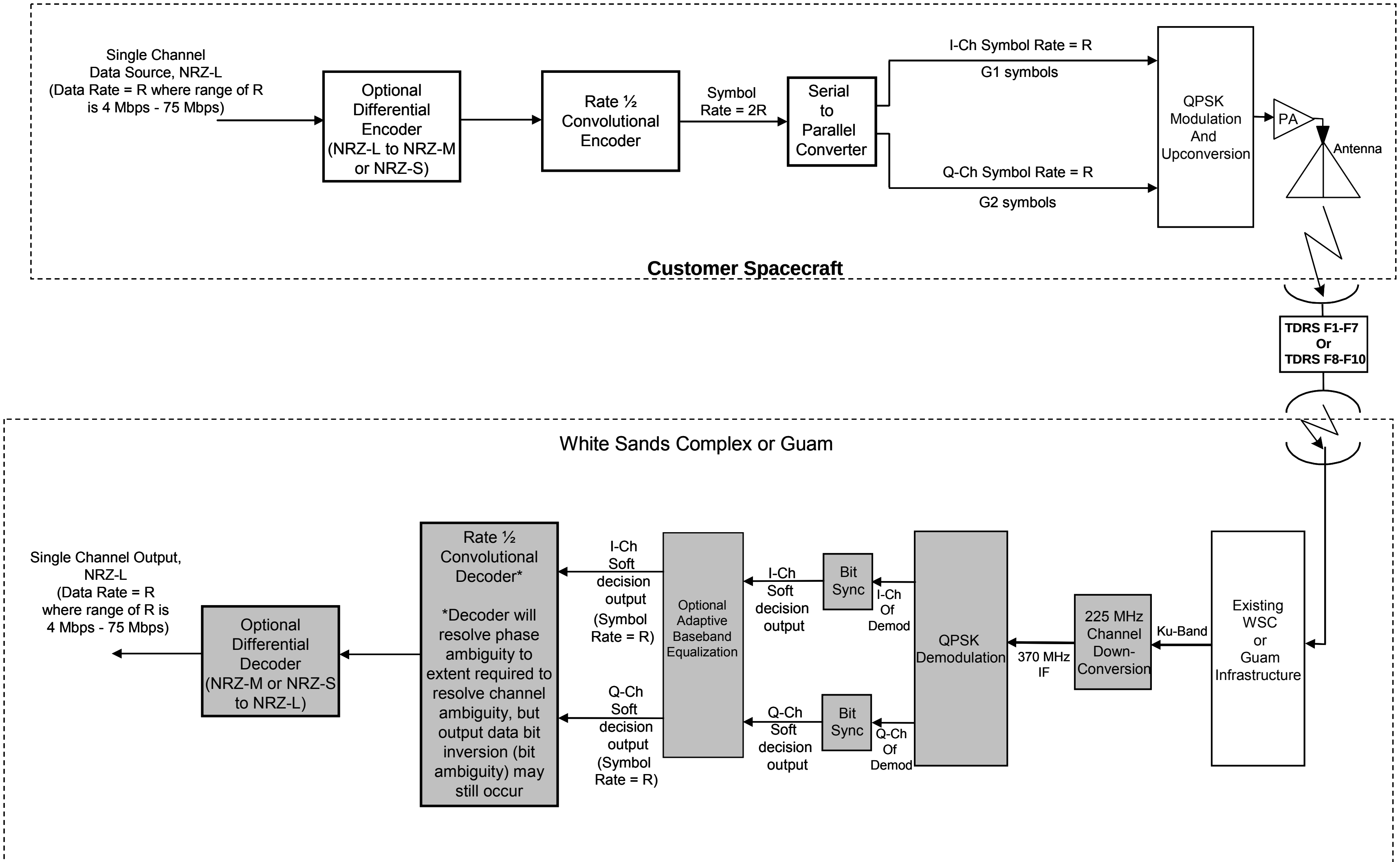
Figure C-4. Coded QPSK, Dual Channel Configuration, Coding on Both Channels



: New or upgraded equipment under TKUP

NOTE: Encoding can be on I-channel or Q-channel, therefore, $R_{I-ch} \leq 150$ Mbps and $R_{Q-ch} \leq 75$ Mbps is also a valid configuration

Figure C-5. Coded QPSK Dual Channel Configuration, Coding on Only One Channel



: New or upgraded equipment under TKUP

Figure C-6. Rate ½ Coded QPSK, Single Channel Configuration (Alternate I/Q Symbols)

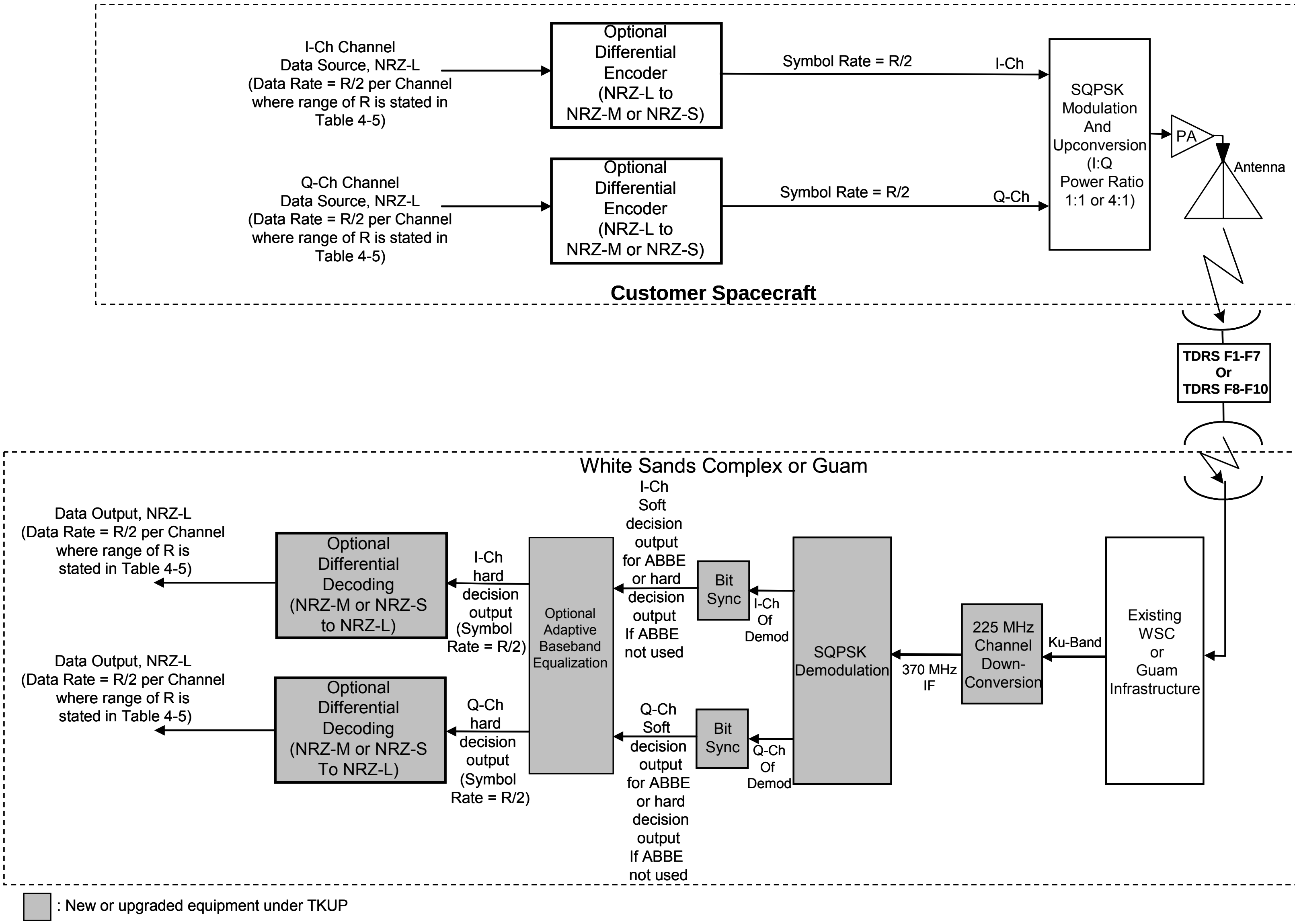
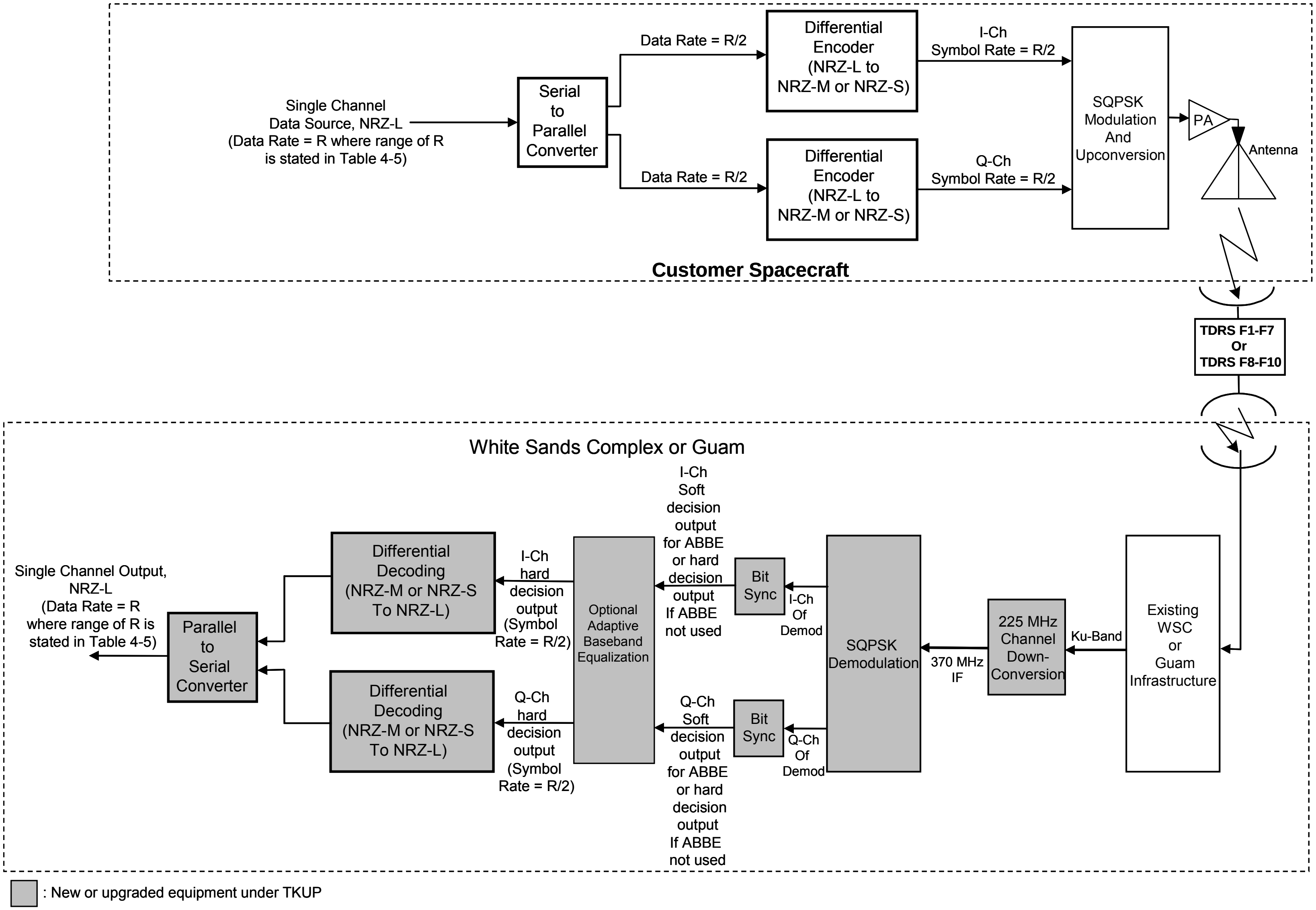


Figure C-7. Uncoded SQPSK, Dual Channel Configuration



: New or upgraded equipment under TKUP

Figure C-8. Uncoded SQPSK, Single Channel Configuration

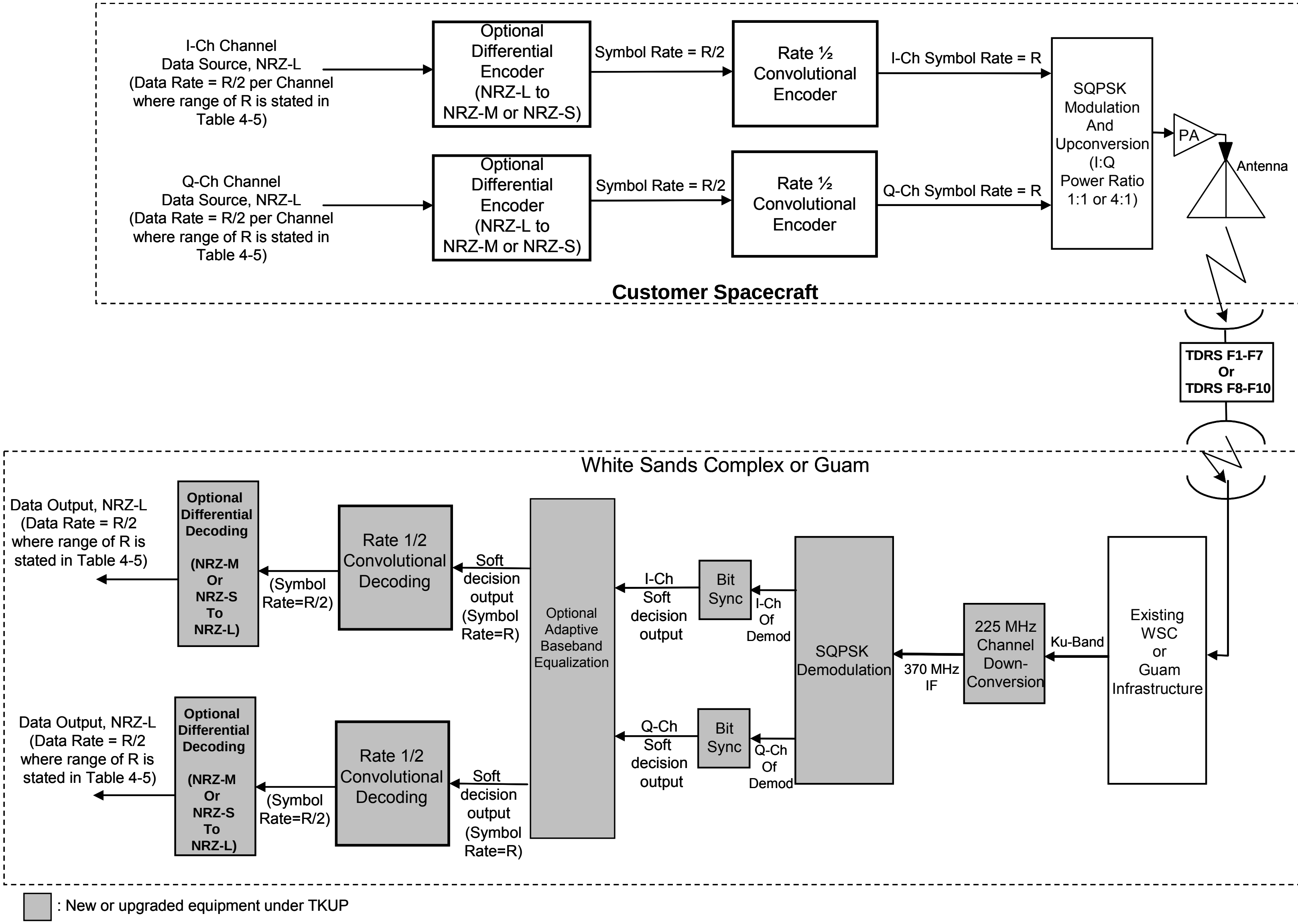
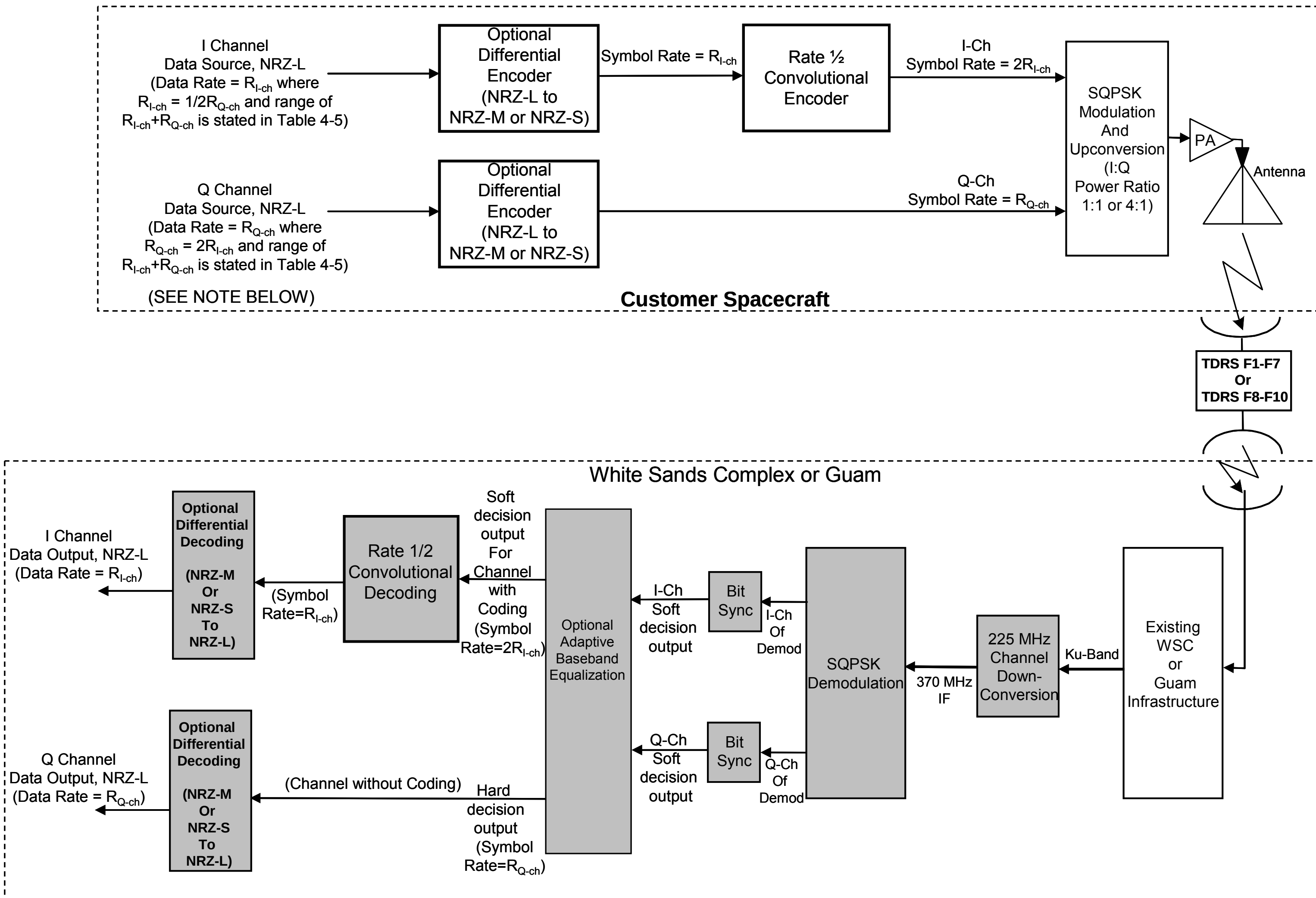


Figure C-9. Coded SQPSK, Dual Channel Configuration, Coding on Both Channels



: New or upgraded equipment under TKUP

NOTE: Encoding can be on I-channel or Q-channel

Figure C-10. Coded SQPSK, Dual Channel Configuration, Coding on Only One Channel

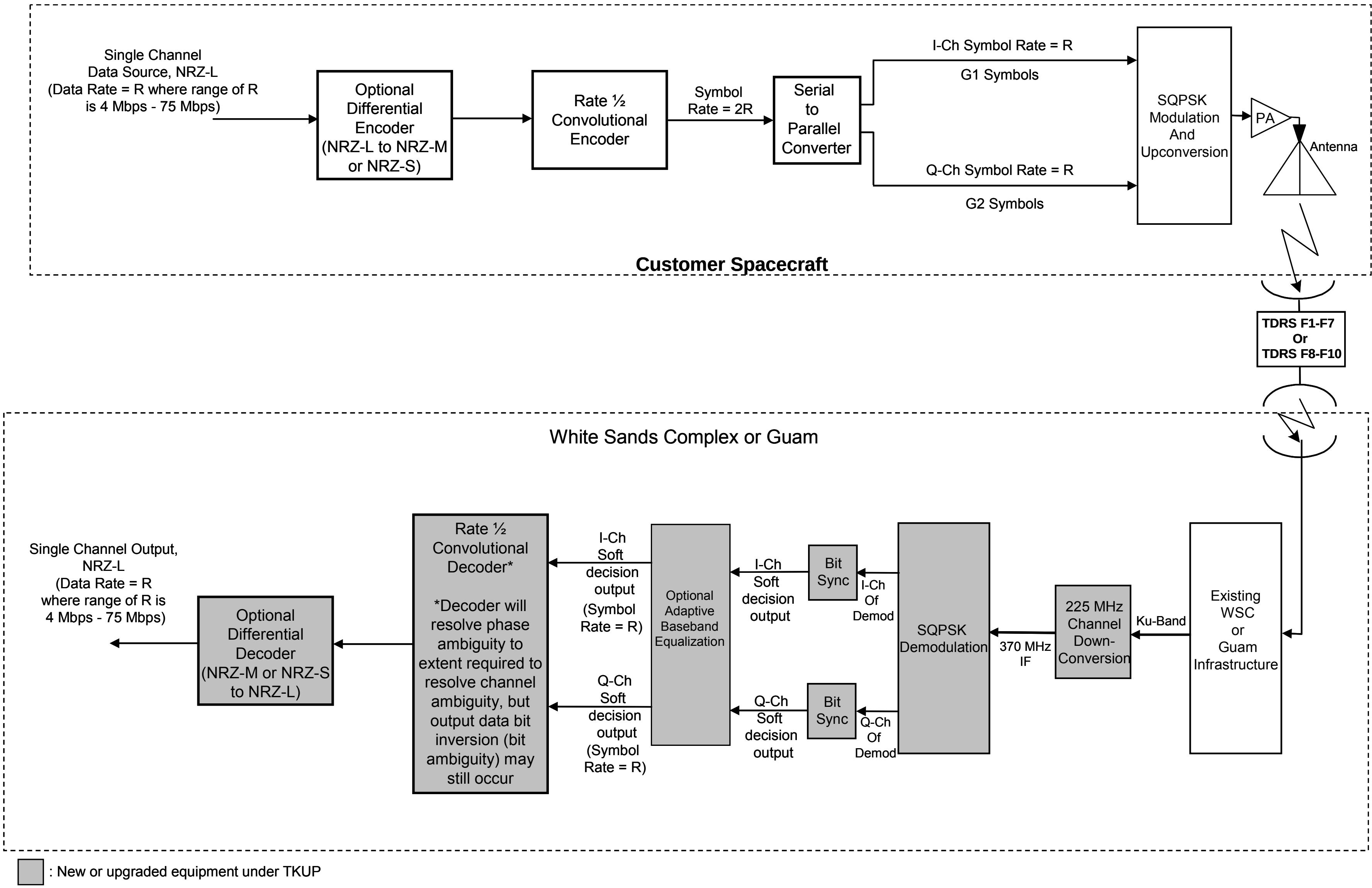


Figure C-11. Rate ½ Coded SQPSK, Single Channel Configuration (Alternate I/Q Symbols)

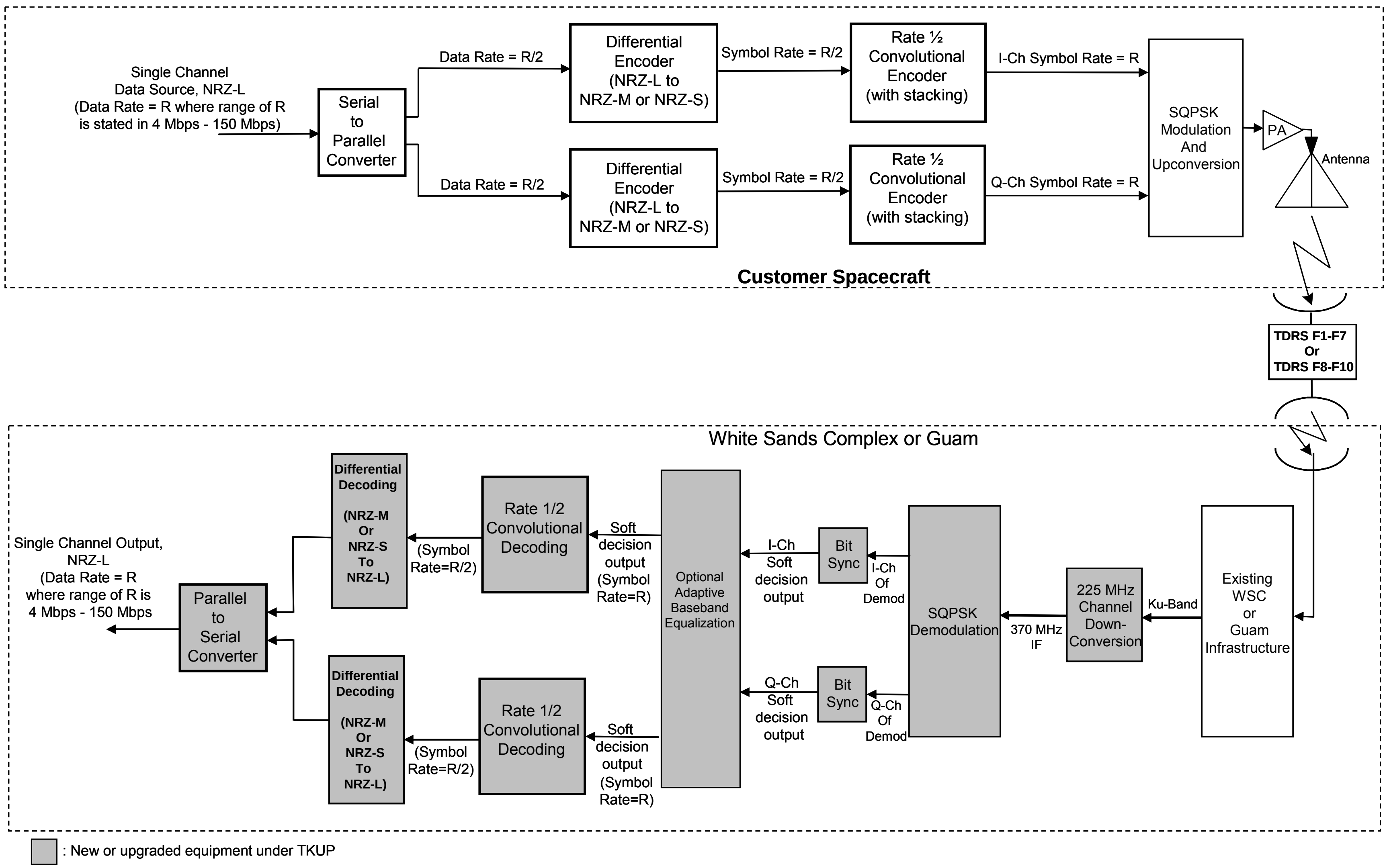


Figure C-12. Rate ½ Coded SQPSK, Single Channel Configuration (Alternate Data Bits)

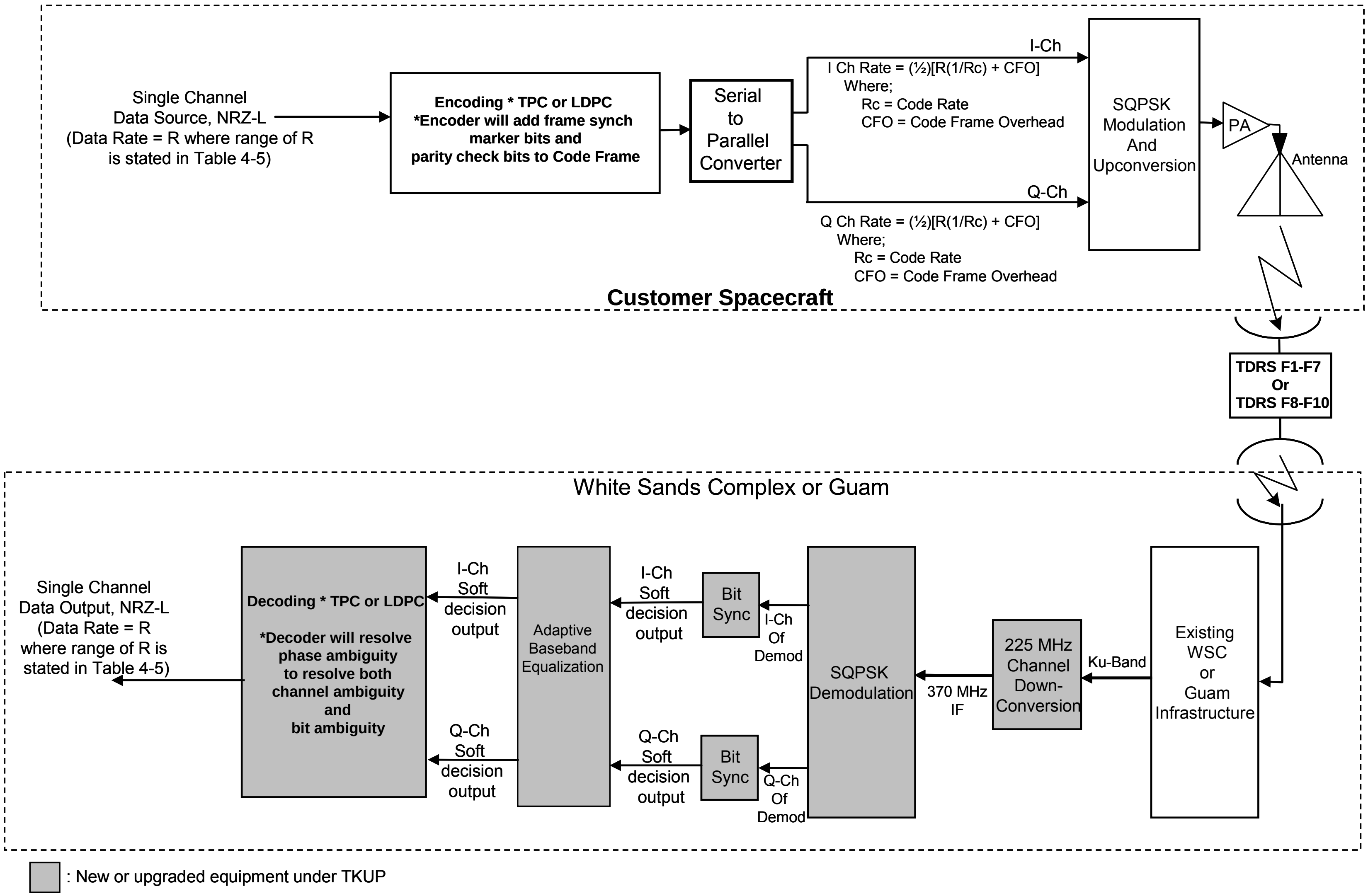
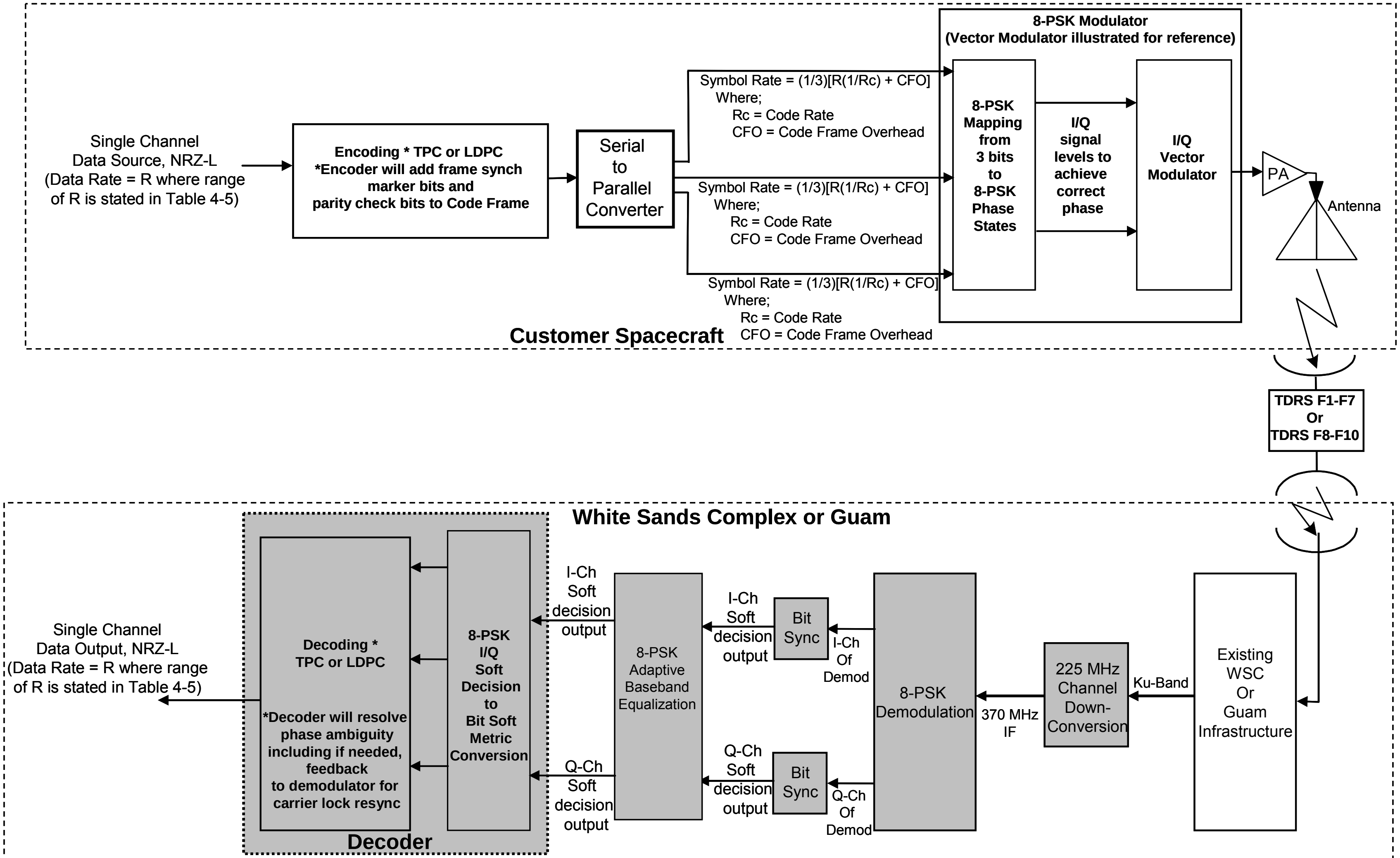
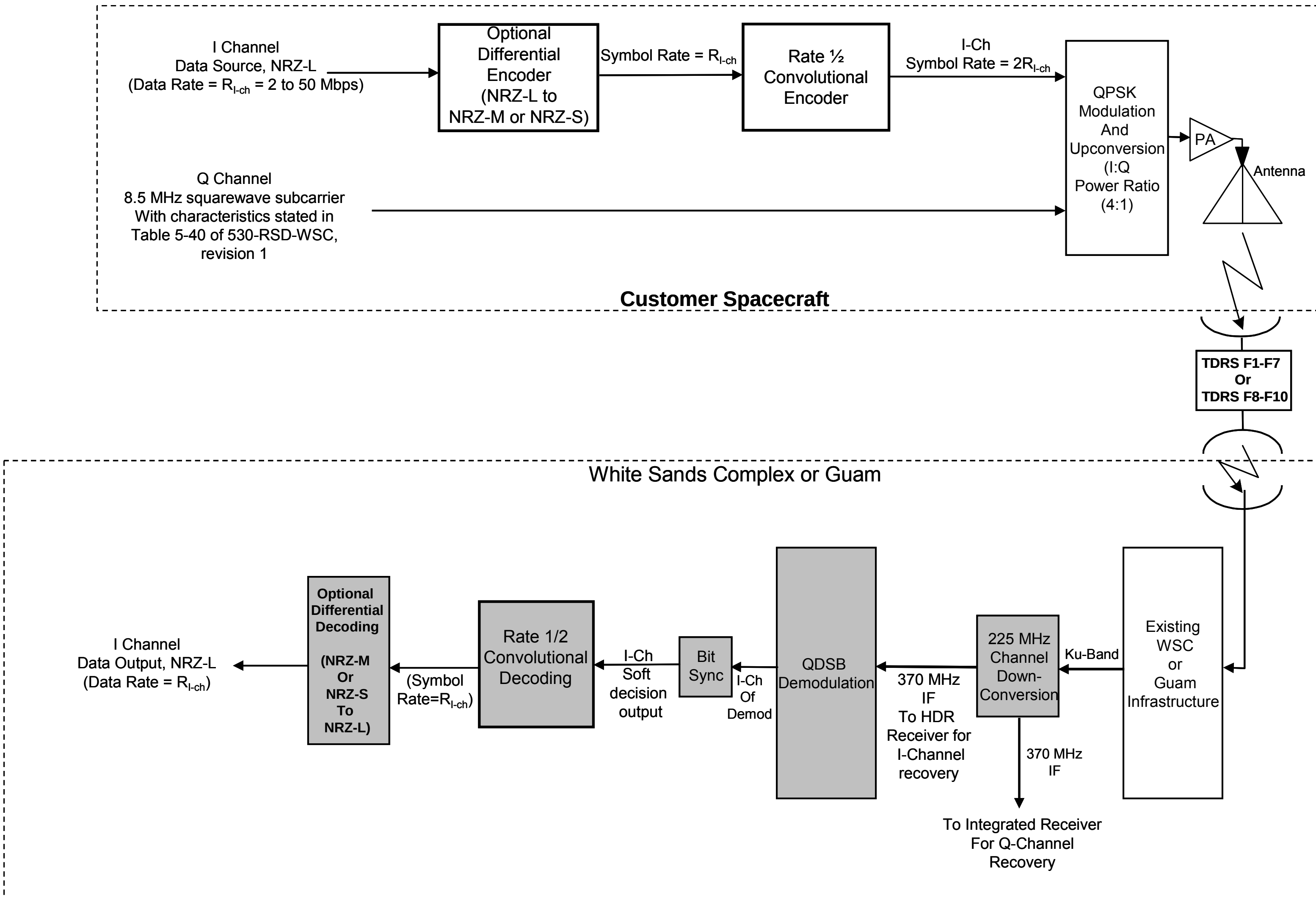


Figure C-13. SQPSK, Single Channel Configuration (LDPC and/or TPC Coding)



: New TKUP Functions at WSC

Figure C-14. 8-PSK, Single Channel Configuration (LDPC and/or TPC Coding)



: New or upgraded equipment under TKUP

Figure C-15. KSHR Mode 1 Configuration

APPENDIX D. ECL SIGNAL SPECIFICATIONS

D.1 Differential ECL Input Signal Specifications

The legacy differential inputs of the HRDS accept non-return to zero-level (NRZ-L) input data synchronous with input clock. The HRDS inputs operate with data between 2 and 300 Mbps with synchronous clock operating at frequencies between 2 and 300 MHz. Each input is common mode differential, and provides an input impedance of 50 ohms +/- 1.0 percent. The differential inputs are individually terminated with 50 ohms to –2V.

Minimum differential input performance is maintained within timing and voltage parameters as defined in Table D-1. The data and clock signal conventions are shown in Figure D-1. See Figure D-2 for nominal differential ECL terminations.

Table D-1. Differential Input Characteristics

PARAMETER	CHARACTERISTIC
DATA FORMAT:	NRZ-L
INPUT VOLTAGE (at differential receiver): DIFFERENTIAL INPUT VOLTAGE, A-to-B	150 mV (min) 1000mV (max)
RISE TIME: 20 to 80%	600 ps MAX
FALL TIME: 80 to 20%	600 ps MAX
CLOCK SYMMETRY:	45 to 55%
DATA TO CLOCK JITTER & SKEW: (AT RACK INPUT I/O PANEL)	
2 Mbps to 150 Mbps	200 ps JITTER 800 ps SKEW
150 Mbps to 300 Mbps	100 ps JITTER 400 ps SKEW
DIFFERENTIAL SKEW (DATA A to DATA B or CLOCK A to CLOCK B)	70 ps MAX

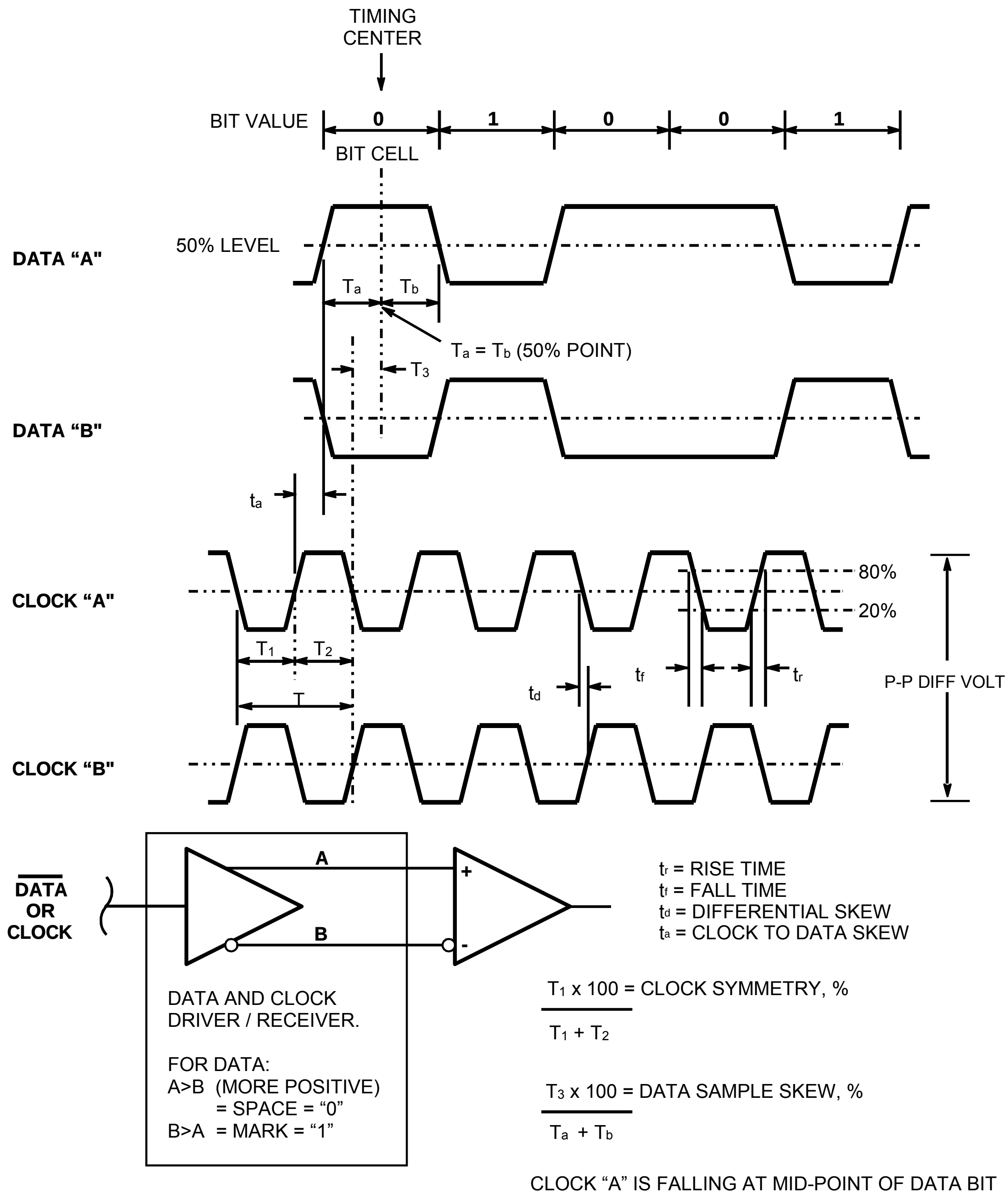


Figure D-1. Differential Data and Clock Signal Conventions

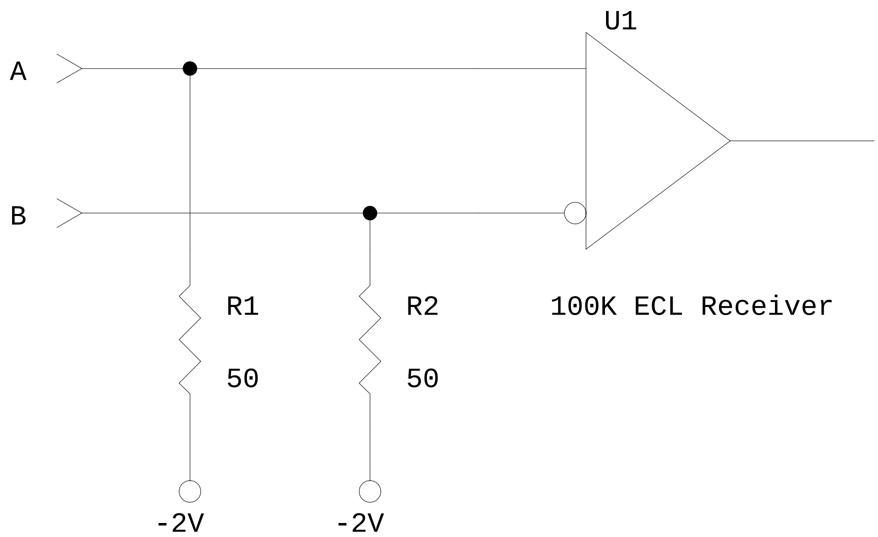


Figure D-2. Nominal Differential ECL Termination

D.2 Differential ECL Output Signal Specifications

The legacy differential outputs of the HRDS provide contiguous non-return to zero-level (NRZ-L) data streams synchronous with output clock. The HRDS operates with output data rates between 2 and 300 MBPS with synchronous clock operating at frequencies between 2 and 300 MHz. Each output is common mode differential and sources a nominal output impedance of 50 ohms.

The data and clock signal conventions are shown in Figure D-2. Minimum differential output performance is maintained within timing and voltage parameters as defined in Table D-2**.**

Table D-2. Differential Output Characteristics

PARAMETER	CHARACTERISTIC
DATA FORMAT:	NRZ-L
OUTPUT VOLTAGE: DIFFERENTIAL OUTPUT VOLTAGE AT HRDS OUTPUT CONNECTOR	700 mV (peak-to-peak) Minimum
RISE TIME: 20 to 80%	600 ps MAX
FALL TIME: 80 to 20%	600 ps MAX
CLOCK SYMMETRY:	45 to 55%
DATA TO CLOCK JITTER & SKEW: (AT RACK OUTPUT I/O PANEL) 2 Mbps to 300 Mbps	200 ps JITTER MAX 700 ps SKEW MAX
DIFFERENTIAL SKEW (DATA A to DATA B or CLOCK A to CLOCK B)	85 ps MAX

Abbreviations and Acronyms

8-PSK	8-Ary Phase Shift Keying
ABBE	Adaptive Baseband Equalizer
ADPE	Automatic Data Processing Equipment
AGC	Automatic Gain Control
A_i	Inherent Availability
AM	Amplitude Modulation
A_o	Operational Availability
ASM	Attached Sync Marker
ATR	Autotrack Receiver
AWGN	Additive White Gaussian Noise
BB	Baseband
BER	Bit Error Rate
BERTS	Bit Error Rate Test System
BPSK	Binary Phase Shift Keying
C/N_o	Carrier-To-Noise Power Spectral Density Ratio
CCB	Configuration Control Board
CCI	Common Carrier Interface
CCR	Configuration Change Request
CCSDS	Consultative Committee for Space Data Systems
CDCN	Control and Display Computer Network
CFO	Code Frame Overhead
CMM	Capability Maturity Model
COST	Commercial-Off-The-Shelf
CSCI	Computer Software Configuration Item
CTFS	Common Time and Frequency System
CW	Continuous Wave
dB	Decibel
dBc	dB Referenced To The Carrier
dBm	dB Referenced To One Milliwatt
dBW	dB Referenced To One Watt
DCN	Document Change Notice
DG	Data Group
DIS	Data Interface Subsystem

DOD	Department Of Defense
DPF	Data Processing Facility
E_b/N_o	Energy per Bit-To-Noise Power Spectral Density Ratio
ECL	Emitter-Coupled Logic
EET	End-To-End Test
EIRP	Effective Isotropic Radiated Power
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
F	Fahrenheit
FM	Frequency Modulation
G/T	Gain-To-Noise Temperature Ratio
GDIS	Guam Data Interface System
GHz	Gigahertz
GRGT	Guam Remote Ground Terminal
GSFC	Goddard Space Flight Center
HDDR	High Density Digital Recorder
HDLC	High Level Data Link Control
HDR	High Data Rate
HMD	Hardware Maintenance Depot
HRBS	High Rate Black Switch
HRDS	High Rate Digital Switch
HWCI	Hardware Configuration Item
Hz	Hertz
ICD	Interface Control Document
ID	Identification
IF	Intermediate Frequency
IFL	Intra-Facility Link
IP	Internet Protocol
IR	Integrated Receiver
IT	Information Technology
ITS	Information Technology Systems
KaSAF	Ka-Band Single Access Forward
KaSAR	Ka-Band Single Access Return
kHz	Kilohertz
KSA	K-Band Single Access

KSAF	K-Band Single Access Forward
KSAR	K-Band Single Access Return
KSHR	K-Band Shuttle Return
KuSAF	Ku-Band Single Access Forward
KuSAR	Ku-Band Single Access Return
LAN	Local Area Network
LDPC	Low Density Parity Check
LHC	Left-Hand Circular
LI	Local Interface
LO	Local Oscillator
LRBS	Low Rate Baseband Switch
LRDS	Low Rate Data Switch
LLR	Log-Likelihood Ratio
LRU	Line Replaceable Unit
Mbps	Megabits per Second
MHz	Megahertz
MMI	Man Machine Interface
MOC	Mission Operations Center
MTBF	Mean Time between Failures
MTG	Maintenance Test Group
MTTR	Mean Time to Repair
N/A	Not Applicable
NASA	National Aeronautics and Space Administration
NCCDS	Network Control Center Data System
NISN	NASA Integrated Services Network
NIST	National Institute of Standards Technology
NRZ	Non-Return to Zero
NRZ-L	NRZ-Level
NRZ-M	NRZ-Mark
NRZ-S	NRZ-Space
ODM	Operations Data Message
OPM	Operations Message
PMMS	Performance Measuring and Monitoring Subsystem
PN	Pseudo-Random
PPS	Pulse Per Second

PRBS	Psuedo Random Bit Stream
PTE	PMMS Test Equipment
QA	Quality Assurance
QDSB	Quadrature Double Sideband
QPSK	Quadrature Phase Shift Keying
RF	Radio Frequency
RFI	Radio Frequency Interference
RHC	Right-Hand Circular
RMA	Reliability/Maintainability/Availability
rms	Root-Mean-Square
RS	Requirements Specification
SA	Single Access
SAA	Single Access Antenna
SCM	Software Configuration Management
SEI	Software Engineering Institute
SFCG	Space Frequency Coordination Group
SGL	Space-Ground Link
SGLT	Space-Ground Link Terminal
SHO	Scheduling Message
SISO	Soft Input Soft Output
SLR	Service Level Report
SMTF	Software Maintenance and Test Facility
SN	Space Network
SNAS	Space Network Access System
SNEGS	Space Network Expansion Ground System
SNIP	Space Network Interoperability Panel
SNR	Signal-To-Noise Ratio
SNUG	Space Network Users' Guide
SQPSK	Staggered QPSK
SSB	Single Side Band
SSC	Subsystem Controller
SSL	Space-To-Space Link
STGT	Second TDRSS Ground Terminal
SWSI	Space Network Web Services Interface
SWSI	Space Network Web Services Interface

TDRS	Tracking and Data Relay Satellite
TDRSS	Tracking and Data Relay Satellite System
TKUP	TDRSS KSAR Upgrade Project
TOCC	TDRSS Operations Control Center
TPC	Turbo Product Code
TT&C	Tracking, Telemetry, and Command
UQPSK	Unbalanced QPSK
UTC	Universal Time Coordinated
VAC	Volts Alternating Current
VSWR	Voltage Standing Wave Ratio
WSC	White Sands Complex
WSGT	White Sands Ground Terminal

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